ARCHITECTURAL RECORD

The Future of Architecture and Practice:
What You Need to Know

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ARCHITECTS TODAY need to be more than just great designers in order to succeed, especially in their own practices. Knowledge of costs and other determining factors can make the difference in winning a job and managing it effectively. The attached eBook contains valuable information about paths to advancement for architects outside of their design expertise. We hope you find this valuable.

Alex Bachrach, Publisher
ARCHITECTURAL RECORD

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"The level of detail that we are able to generate with RSMeans data shows that [our] company understands the details of the designs we do and the impacts that the initial designs as estimated through final design."

John Bolton, Architect, CTA

Discover more at rsmeans.com/designdata

GORDIAN®

MINIMIZE THE RISK OF COST OVERRUNS WITH ACCURATE COST DATA

Author: Derrick Hale, PE, PMP, Sr. Engineer, Gordian

When planning a future construction project, whether it is a new build or renovations to an existing building, careful budgeting is key to avoiding cost overruns. These overruns can lead to more than just a frustrated client—they can shut down a construction project altogether.

That's why accurate and recent construction cost data is essential to project planning and estimating. Old data cannot give a comprehensive and accurate view of tomorrow's project. All-inclusive and current construction cost data should serve as a check to historical records.

Using old data won't account for often notable changes in material, labor and equipment prices. Fluctuations in the costs of raw materials, energy costs and local labor rates—to name a few—also need to be accounted for.

Estimating in greater detail, or even at a conceptual level, is made easier by using predictive cost data. By minimizing the possibility of cost overruns, accurate project plans lessen the chance of surprise price disputes. And if a change is necessary, construction cost data prepares those involved for exact pricing discussions, without the tension.

Not only does accurate construction cost data prepare project budgets for the future, it also lays the foundation for clear project expectations and fewer pricing conflicts. Further, relevant data creates insights about the future of your project without neglecting important changes to costs. RSMeans data invests exhaustive hours into cost research to develop construction cost databases. Coupling this validated, researched construction cost data with historical information will help you estimate confidently, without the fear of cost overruns. ■

Show Me the Money

IMAGE: © MADMAXER/GETTY IMAGES

Architects must change the profession's value proposition and find new ways to do business.

BY PHIL BERNSTEIN

A RECENT headline in Britain's tabloid *Express* read, "Construction jobs BOOM: Bricklayers and plasterers earn MORE than architects." It seems that skilled construction workers in the UK are at the front of the pay line, with architects bringing up the rear. Ouch. But architects reading this headline on either side of the Atlantic are hardly surprised.

There's an oft-repeated trope in our profession that we're underappreciated, losing ground to specialists, and under the thumb of contractors. Most architects have their own version of these complaints, but, unfortunately, they reflect the reality of the essential value proposition of architecture as a profession. Despite the relative strength of the current economy, architects are still paid far less than comparable professionals of equal education and import, and we create value through outmoded delivery systems where the client's first—and often most important—priority is getting the lowest fee from the architect. When your price is driving selection, you're a commodity.

Let's examine the economic dynamics of this syndrome, and then I would like to challenge the current methods of value creation and propose a new business model for architects.

Why the Value of Architectural Services Is Depressed

First, some economic basics: according to AIA statistics, American architects are responsible for designing about $600 billion worth of buildings each year, for which they are paid approximately $29 billion in fees, or about 4.8 percent of construction value. Those fees are largely paid as a commodity, mostly as lump sums or versions of a fixed fee (like percentage of construction). But real value is rarely reflected when compensation is a commodity, and that is hurting the overall economics of the profession.

Other professions have much better value propositions, and that shows up in their paychecks. There are about 110,000 licensed architects in the U.S. and about 106,000 billable positions in U.S. firms. Compared to the 950,000 practicing physicians and 1.33 million lawyers, we're a pretty rare resource. Nonetheless, the salaries of architects—as a proxy for how well we convert our value in the marketplace of building—are depressed, and that's depressing.

PROFESSION	STARTING SALARY	6–10 YEARS OUT
Architecture	53,900–65,000	137,060–157,360
Medicine	53,000–62,000	267,500–489,000
Law	110,000–180,000	271,950–391,300

At Yale, where I teach, three of the professional schools accredited for licensure (Law, Architecture, and Medicine) make for an interesting comparison of starting and early-career salaries for graduates, who presumably are in high demand and able to command paychecks at the high end of the spectrum:

The architecture profession today is far leaner and meaner than its pre-crisis state in 2009, likely due to new technology. Net revenues of American firms have largely recovered from the dip, having returned to their 2008 peak by 2015. But firm staffing has decreased by 17 percent, from 128,000 billable positions in 2008 to just 106,000 in late 2016, meaning 22,000 fewer in staff are doing roughly the same amount of work. Salaries are showing modest rises but fee percentages probably lag pre-crisis levels, and since employees haven't seen 17 percent increases in their paychecks, the productivity gain may be even higher. And while there are no well-understood measures of architectural productivity, there is a strong correlation between this productivity jump and adoption of advanced technologies like BIM in our discipline. But efficiency merely drives prices down further in a market where time spent isn't related to value delivered.

Are Architects Selling Time or Results?

Commoditized fee structures, salary pressure, and low profit margins are all symptoms of a larger disease: the actual value that architects create is not realized for them financially. Buildings are central to civilization itself, and absolutely necessary not just for survival but progress. As insurance companies remind us relentlessly, designing things is risky business, but the business risk of practice (running out of money) is not correlated to liability risk (getting sued), unlike the way it is in almost every other market where assuming higher risk means a higher reward. The economic models for designing and building—how architects and builders are selected and contracted—are almost exclusively driven by getting the lowest price, irrespective of the desired result. Enormous waste (as much as 35 percent of construction costs), ineffectiveness (where around 30 percent of all projects miss budgets and schedules), and environmentally irresponsible building (resulting in 40 to 50 percent of the carbon contributing to climate change) are the outcomes. Clearly, there is lots of room for improvement.

Designing and building remain risky, questionably profitable, unpredictable, and often just not very much fun.

Once upon a time, contracts in our business were gentlemen's agreements (and they were, unfortunately, all gentlemen). But, since then, various experiments in project-delivery models—construction management, design-build, "early contractor involvement," design assist—have each attempted to make the industry more effective. Whether "bring the contractor on early!" (construction management), or "create one line of responsibility" (design-build), or "let the builders do the working drawings" (design assist), each of these attempted to improve the ends without a careful reexamination of the means. None of these techniques, despite episodic success, has improved the productivity, profit margins, results, or even the pleasure of working in the building industry itself.

But focusing exclusively on productivity and cost/schedule conformance is to miss the real opportunity for change, like measuring the success of surgery not by whether the patient is cured but by how fast the procedure was completed. There is another way: shifting the value propositions of practice from selling time to creating results for clients. Compensation models could be based on delivering outcomes of the building process itself, including the performance of the finished building. This isn't just magical thinking—rapidly evolving technologies that combine the computational power of the cloud, the representational potency of digital models, and the analytic capabilities of simulation software are already allowing designers to predict aspects of building more accurately—cost estimating with more quantitative precision, energy consumption based on use, even embodied energy and carbon. It is just a matter of time before these technologies expand the predictive reach of the architect into occupant behavior, building life cycle performance, even usage outcomes like employee satisfaction or staffing efficiencies.

The economic models for designing and building are almost exclusively driven by getting the lowest price, irrespective of the desired result.

Using Digital Tools to Drive Results and Innovate Practice

The implications of this strategy are far more profound than just new contracts and fee formulas or fancy digital simulation tools. The predictive power of new digital tools can amplify our abilities as designers to solve complex "wicked problems," as theorist Horst Rittel puts it, and create new, important, and valuable solutions for clients willing to pay for them. But practice models, design methods, and our willingness to take responsibility for the results of our work, will need radical reform.

We could start with the immediate challenges of cost and schedule conformity, working in concert with our builder collaborators to assure clients that these basic objectives of design and construction can be accomplished—and we should be rewarded when they are (and punished when they are not). Establishing credibility from there, we could move on to building-performance objectives like energy usage, carbon emissions, even maintenance-cost optimization. Ultimately, an outcome-based delivery system could connect the purpose of a building—offices to boost the effectiveness of workers, schools to teach better, hospitals that promote faster healing—with the architect's ability to realize those goals. These changes in the business model can't be implemented by architects unilaterally, but clients would certainly welcome any strategy where the architect, with skin in the game, is truly invested in project-based outcomes that are both in the client's and the architect's interest.

Examples of result-based fees have been gaining momentum in construction: architects paid to provide subcontractors with digital data under design-bid-build; shared conditions based on selected outcomes in CM at Risk contracts; integrated teams under design-build; outcome-based profit objective paid under Integrated Project Delivery (IPD). Architects empowered by predictive and simulative tools (and, soon enough, bolstered by machine learning and big data) can operate with more powerful agency to create greater value for clients.

And here's where today's innovation culture can meet the challenges of outcome-based practice; technology might be necessary, but it's not sufficient to create ideas of new value, and technology's potential will go unrealized without equal inventiveness in new business models, practice approaches, and willingness to experiment with definitions of architectural services. In the past several years, I have observed a dramatic shift in the interests of my architecture students, who are increasingly dissatisfied with the standard platforms, obligations, and rewards of traditional practice; they have lost their enthusiasm for establishment firms. They're taking courses outside the architecture school at the business school, some even earning MBAs to go with their M. Arch.'s. They are studying and generating innovative business models, creating start-ups, joining hackathons, and seeking jobs with firms led by architects who are also entrepreneurs, researchers, builders, and developers. This is good news for the profession: a generation of fresh talent demanding new ways of practice, moving ahead with both youthful enthusiasm and a blissful ignorance of our inglorious past.

The architect and mathematician Christopher Alexander once suggested that architectural design was the obligation to create "an intangible form in an indeterminate context." This can certainly be true of the serious, ineffable qualities of good design. But in our modern age, the practical context is increasingly determinate, and outcome-based design practice—enabled by new attitudes, business models, and technology—will empower us to deliver the real value of both. ■

HOW PREDICTIVE DATA IS REVOLUTIONIZING PRECONSTRUCTION PLANNING

Preconstruction planning has been, and continues to be, one of the most challenging aspects of the building life cycle. Design professionals often rely on yesterday's data to plan tomorrow's projects. However, historical data has proven to be unreliable as it does not include factors for present markets or track trends impacting costs. Nevertheless, architects and other design professionals are expected to provide a project budget as well as stick to it.

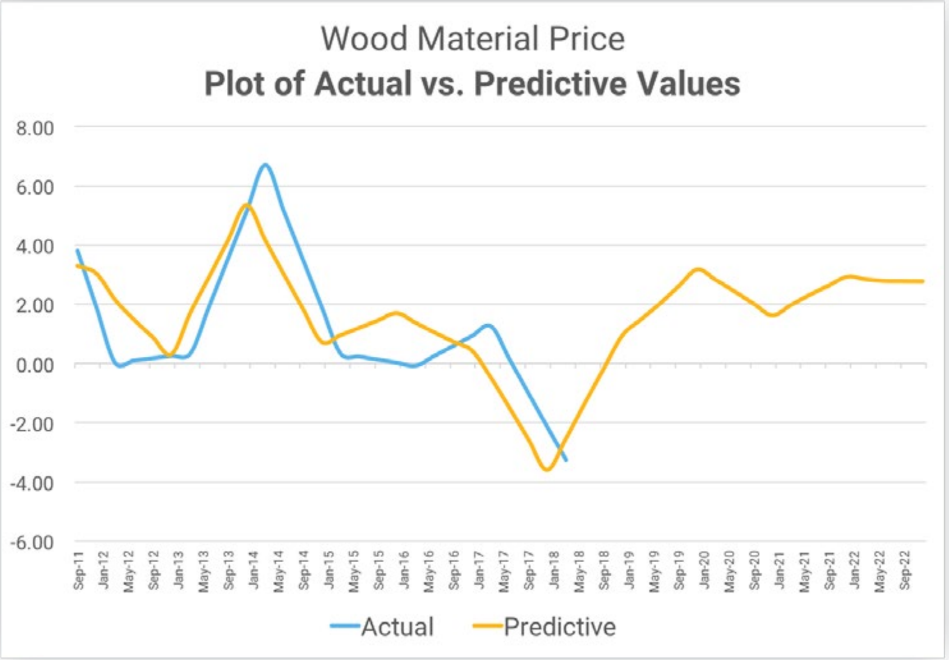
Thanks to modern data science and predictive analytics, those involved in the construction planning phases are now able to supplement historical data with reliable projections of future costs. Predictive cost data was developed by using a hybrid methodology combining classical econometric techniques with contemporary data mining procedures to address the shortcomings of traditional forecast data.

Problem

Until the economic crash of 2008, construction professionals relied on historic prices and localization factors to provide reasonably accurate costs to build. While these costs and factors are helpful when putting a budget together, stakeholders have increasingly voiced dissatisfaction with their accuracy (or lack of). Roughly 98 percent of construction projects go overbudget.[1] Further, market volatility and a shrinking construction labor pool have contributed to the inability to rely on past data for budgetary purposes. Volatilities can be brought about by labor shortages, tariffs and natural disasters. But also contributing to market volatility is the fact that the construction industry shows some of the lowest technology adoption rates

Prior to 2008, projects moved forward without major concerns about volatile costs. During and following the economic crash, a large number of contractors were forced to leave the construction industry. When owners and builders were able to begin planning for regrowth, the construction labor force had been reduced by three-fifths.

Historic building costs and factors used in previous years became obsolete. More importantly, boards of directors and investors' concerns about the escalating costs grew exponentially. This led to a higher standard of accountability for construction and design professionals to manage and adhere to forecasted budgets as material, labor, and equipment rates account for 79 percent of total construction costs on average[2] Overhead and profit make up the remaining 21 percent, including workers comp, state and federal unemployment costs, social security and public liability costs, plus an estimated profit percentage for material and equipment for the installing contractor. There is a clear need for diligent management of construction material and labor costs.



A comparison of predictive versus actual costs for a specific building material.

When using current data at the capital planning stage—typically six to 24 months before construction starts—it becomes impossible to maintain an accurate estimate by the time the project breaks ground. Throughout the planning phase and all the way through construction, numerous unknowns could cause unforeseen cost increases. Material prices can fluctuate greatly year-over-year based on interactions of various commodities and construction volume. Without a reliable method to keep track of all the moving parts, blown budgets, broken processes, and finger-pointing ensues. This can not only slow a project greatly, but also grind it to a halt.

Solution

Traditional forecasting data, developed during a time of far less computing power and limited availability of 'big data,' simply does not meet today's needs for accurate planning and budgeting. Traditional economic forecast methods do not predict market swings or sharp cost escalations well. Although based on econometric principles and modeling techniques, predictive cost data differs from traditional econometric forecasts in two ways.

First, traditional forecasts are based on macroeconomic theory, even when analysis of historical values of those macroeconomic indicators demonstrates them to be statistically insignificant predictors. Predictive cost models disregard theory altogether and are based exclusively on data-driven empirical evidence.

This empirical evidence is the result of extensive exploratory data analysis and pattern-seeking visualizations of historical cost data with economic and market indicators. This approach, clearly an update to the centuries-old, theory-driven process, has been extensively researched and validated by Edward Leamer, professor of global economics and management at the University of California, Los Angeles (UCLA).[3] Only economic indicators that have 'proven themselves' in exploratory analysis become candidates for model development, testing, validation, and resulting predictive cost estimates.

Building teams can employ predictive cost data to accurately predict the cost of the construction before the project breaks ground.

Second, predictive cost data uses mining techniques and principles to improve traditional econometric modeling practices. This family of processes and analyses has evolved since the 1990s from a mix of classic statistical principles and more contemporary computer science and machine learning methods.

Data mining methodology is specifically designed to analyze observational data instead of experimental information. A robust methodology, data mining takes advantage of recent increases in computing power, data visualization techniques, and updated statistic procedures to find patterns and determine drivers of construction material and labor cost changes. Measures of these drivers and their relationships to each other and to construction costs, along with their associated lead or lag times, are represented in a statistical algorithm predicting future values for a defined material and location.

Predictive data and the future of preconstruction

Quality predictive models are constantly monitored for degeneration, which is to be expected as economic and market conditions change. Decisions can be made as to whether a model needs to be refit or rebuilt based on quarterly updates of external economic, construction-specific, and market condition indicator data. Additionally, special analyses and model checking can be performed as changes in market conditions are announced, such as tariffs imposed on steel and aluminum.

Where traditional economic forecasting techniques are simply unable to predict cost volatility and sudden market changes, predictive cost data provides a more robust and accurate data-driven alternative.

One of the big challenges for design teams is creating a budget that is realistic and applicable to current and future stages of a project. On the other hand, construction teams often struggle to manage a budget presented by architecture or contractor teams. By using predictive data, preconstruction professionals can create budgets that consider all of the factors at play in a region, including local labor rates and material costs. This makes it easier to complete a project on-time and within the planned budget.

Predictive cost data has been used to more accurately predict the cost of construction up to three years before the project breaks ground. The ability to have predictive data accounting for real market conditions (amount of construction versus labor availability) and commodity price impacts on material prices is a critical insight in managing the budget from the design through construction. This also gives design professionals the power to instill confidence of their clients in their work. By using predictive data, projects are not only forecasted accurately, they are confidently approved and come to fruition sooner.

Take, for example, a fast food restaurant planning to open 100 new stores over the next five years. Each store will be in a different location and in time the costs of materials and labor will rise and fall in the various markets. Predictive data does more than give an estimate of the total cost or even scaling cost over time, it allows you to optimize the build schedule and determine when and where the next restaurant should be erected.

Looking forward

Conceptual square foot models are typically used in the capital planning phase and fall within 20 percent of actual costs. When applying a predictive database at the material, labor and equipment level and rolling up to these square foot models, back testing resulted in cost deviations of less than three percent up to three years in advance. Back testing included running algorithms to actual data inputs from three years ago and then measured the prediction against the actual data collected three years later on a rolling basis. This means owners, architects, engineers and other construction professionals can confidently utilize predictive algorithms to determine accurate costs to build years in advance..

Applying the same predictive data and algorithm to client-specific models and facilities results in accurate budgetary estimates at the capital planning stage. This accuracy allows construction projects to be completed within the estimated budget. Ultimately, the core value of using accurate predictive cost is the unprecedented ability afforded to construction professionals to understand future costs of projects.

Notes

1 For more information, read “98 Percent of Construction Projects Go Over Budget. These Robots Could Fix That” by Luke Dormehl in *Digital Trends*.

2 Calculated from historical RSMeans data.

3 Read *Macroeconomic Patterns* and Stories by Edward E. Leamer, published in 2009 by Springer-Verlag.

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Simplify the Planning Process

Build out realistic budgets that you can trust with quick access to assembly and square foot level costs.

Avoid Redesign

Align your design with client budgets by verifying costs.

Know Your Options

Seeing where the costs lie is an effective tool for value engineering.

Take the Guesswork out of Estimating

Fill in your knowledge gaps and have the confidence to estimate costs for new scopes, new markets and new places.

Save Time Gathering Costs

Turn estimates around quickly and accurately without relying on subcontractor pricing.

Solve Price Disputes

Quickly come to an agreement on change orders with our impartial industry standard data.

Discover more at rsmeans.com/designdata

Thinking in Approximations

A structural engineer offers a perspective.

BY ROBERT SILMAN

THE USE of computers in analyzing building structures is undeniably a great step forward in our profession. When I trained as a structural engineer in the 1950s, computers were a brand-new wonder, and there were no packaged programs available. If you wanted to use a computer, you had to write the program yourself.

Our firm, Silman, founded in 1966, was one of the first to write its own structural-analysis and design programs. In 1970, we took our successful composite-steel-beam design program to the New York City Department of Buildings and asked them how we should file calculations. Fortunately, they realized that this was the wave of the future and suggested that we develop prototype calculations by hand in the conventional way and then submit parallel results performed by the computer, illustrating that the solutions were the same. To do so, we rented an IBM 1130 with 8k capacity, which was fed by decks of punch cards grinding away for many minutes on fairly simple problems. This became standard protocol for the

Silman completed the renovations of Frank Lloyd Wright's Falling-water (1937) in Bear Run, PA, in 2002. The process required the firm to shore up the main-floor cantilever as well as the waterfall's rocky ledge.

PHOTOGRAPHY: COURTESY SILMAN

Department of Buildings, and the first nine programs filed were from our office.

So I am a great advocate of the use of computers for structural analysis and design, and I always have been. But there are drawbacks. When I was studying structural engineering, I used a slide rule, a wonderful apparatus and now an archaeological artifact. Slide rules help to multiply and divide, provide exponential functions, do logarithms and trigonometry. But the slide rule does not tell you where to place the decimal point. Is the answer 10.00 or 100.00 or 1,000.00?

So most of us, before we even started to fiddle with the slider and the cursor window, estimated the answer in advance. We learned to think in approximations. I can remember designing flat-plate concrete buildings with completely irregular column layouts. We used Hardy Cross's method of moment distribution and generated pages of incredible calculations for different column configurations. The process become repetitive, and we could guess the required reinforcing pretty accurately before putting pen to paper.

This arcane process gave us a "feel" for the buildings that we were designing. They were not some abstract product of machine technology but were rather tactile creations of our very selves. We had used our intuition, which became sharper with experience. There was no way that a large-scale mistake would find its way into the work–we would notice it as a glaring intruder on our orderly process.

In my present role, I review drawings produced by the engineering staff. When I spot an error, the young engineer inevitably will say, "How did you see that so quickly?" I shrug and reply that it was how I was trained, to think about the approximate answer before figuring out the answers. When skipping that intuitive step, one can be easily seduced by computer results that look so neat and orderly.

I am not a Luddite: Our early design methods had enormous shortcomings. Perhaps two of the most grievous were the inability to model the building in three dimensions, as a whole entity, as well as the difficulty in computing building movements. Even structural-analysis problems of modest indeterminacy were often impossible to solve. Anyone could write the compatibility equations, but as the unknowns grew beyond four or five, finding solutions loomed as a lifetime chore.

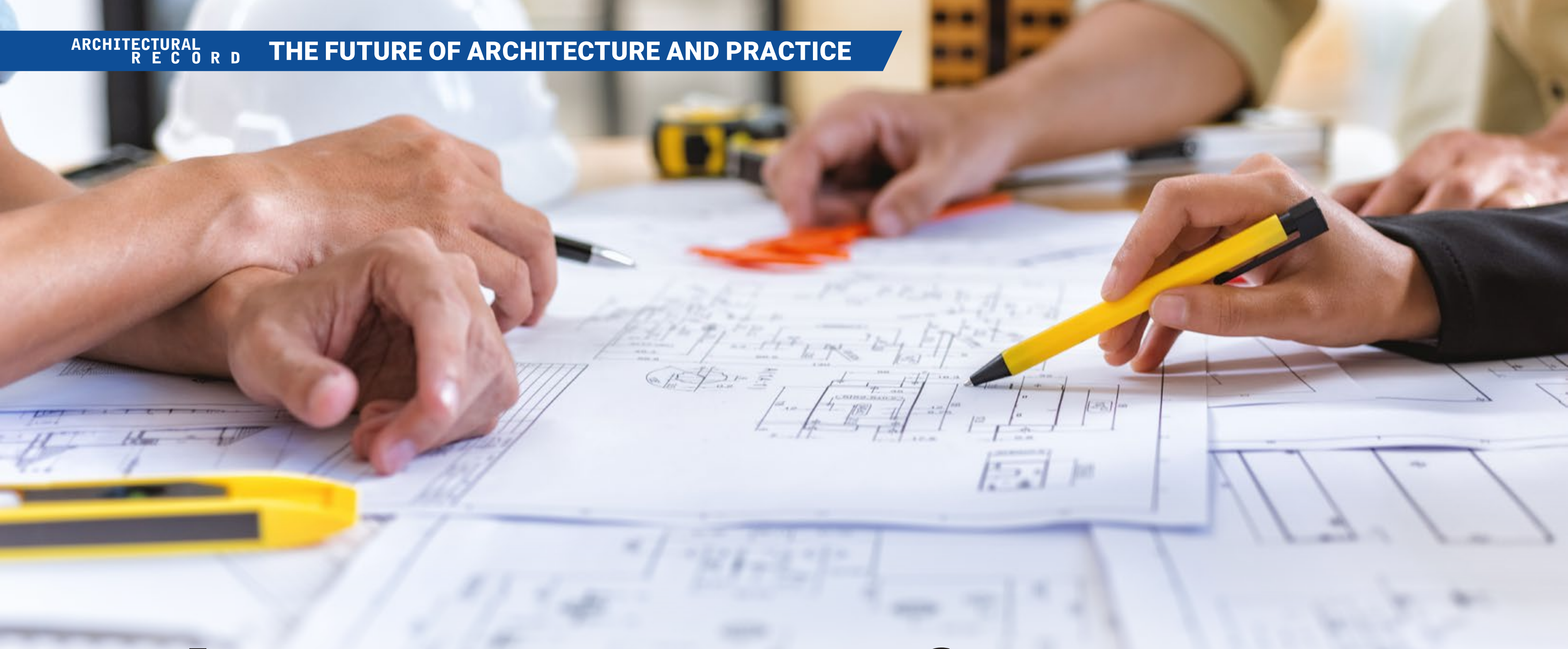
So we developed neat techniques called approximate methods. Large mathematical matrices of the compatibility equations could be partitioned and manipulated with all sorts of tricks. Indeed, some very complicated buildings were analyzed using tricks, and they have behaved beautifully over their lifespans, much to the credit of their designers.

For sure, the complicated geometries and configurations of buildings today could never have been analyzed with any degree of confidence using some of these approximate techniques. Computer analysis provides a higher level of mathematical certainty about the behavior of a structure—advantageous in new construction as well as in the renovation of historic buildings. One example is Fallingwater, which we helped renovate in 2002. To fix the sagging cantilevers, we needed to determine the stresses in the main cantilever girders that support the house. We knew accurately the building geometry and the reinforcing in the girders, as well as the actual deflections that had occurred over the first 60 years. By performing a three-dimensional analysis, and accounting for the participation of the slabs in two-way action by computer, we were able to manipulate various stiffness factors until the calculated deflections of every cantilever matched the actual measured deflections. With this information we could then design the repair, placing the right amount of post-tensioning where needed. Approximate methods would not have provided the precise answer required.

So how do we train ourselves to get the utmost out of computer analysis without losing an intuitive sense of how a building should behave and what its constituent members should look like? And, as our buildings become more complicated, is it really possible to develop that sort of grasp of their structural elements? We should at least start with some training in approximate analysis of simple structures. Like my professor in my first graduate course in indeterminate structures, instructors should demand that, for the first four weeks of the class, students not be allowed to use any mechanical aids–no calculator, no slide rule, and certainly no computer. Professors should encourage them to sketch the shear and moment diagrams and the shape of the deflected structure; they should thus be able to determine the critical points and quantify them within 15 percent accuracy.

It seems to me that we cannot depend wholly on the answers high technology can give us. Rather we must develop a feel for structures by using some of the educational techniques of the past—fostering the ability to see the whole, which technology supports but cannot replace. ■

Robert Silman, president emeritus of Silman, the structural engineering firm, is on the faculty of the Graduate School of Design at Harvard University.

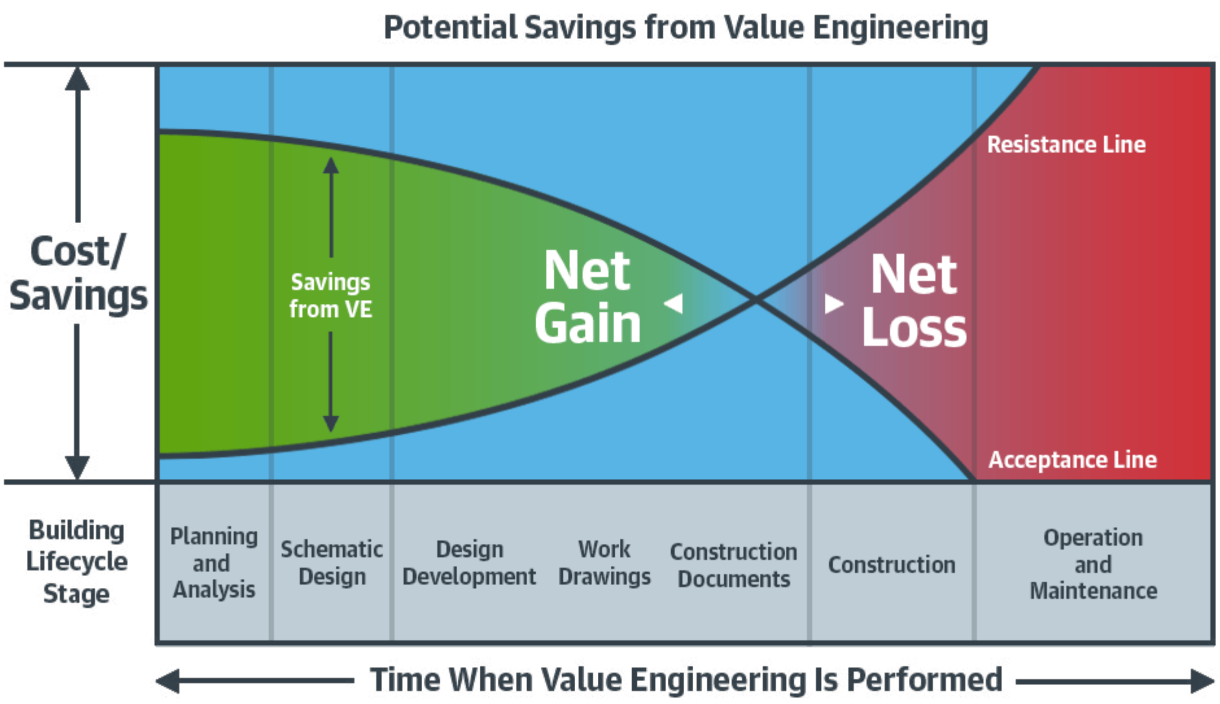


Value Engineering for Construction

Practical. Pragmatic. Function-focused. These terms don't really induce creativity or inspire high-design. Unfortunately, value engineering has gotten a bad reputation as a process where architectural design dreams get dashed. Womp, womp… But the truth is, value engineering can have a positive outcome for all stakeholders—architects, designers and building-product manufacturers included. When everyone embraces and actively participates in value analysis, the benefits can win out and creativity can be used in many different ways to meet the overall goal. This breakdown of value engineering will cover a brief history of its creation, when to use this tested methodology for optimal benefits and what steps are required in the process.

Created in a Crises

Here is a quick history lesson: Lawrence Miles was responsible for purchasing raw materials for General Electric during World War II when manufacturing was at its peak. Sounds like a great gig, but the war caused extreme material shortages. This left Miles searching for suitable alternatives that functioned similarly. He discovered that some substitutes weren't only cost-effective, they were actually better. This realization was the origin of a new technique called "value analysis," more commonly known today as value engineering.



Since its inception, this technique of analyzing value has been widely adopted by many industries and evolved for uses Miles never imagined. Value engineering is used to solve problems, identify and eliminate unwanted costs and improve function and quality. The set of disciplined steps in the value engineering process is meant to optimize initial and long-term investment, seeking the best possible value for the lowest cost.

To VE or Not to VE—That is the Question

Technically speaking, there's no wrong time to value engineer. But the closer the process is to the schematic stage, the better. Planning and design are the two stages of the building lifecycle where value analysis creates the most, well, value. If value engineering becomes rework or causes project delays, it is no longer beneficial to the project. This graph shows when value engineering moves from presenting a financial gain to a financial loss.

Value Engineering during the Building Lifecycle

There is one area where the design team should never compromise: safety. Any change that would result in a violation of building code or otherwise jeopardize the health and well-being of the people who use the facility should be rejected immediately.

It's important to note—value engineering isn't simply a knee-jerk reaction to avoid going over budget. The goal isn't to trim the bottom line, but to maximize function at the lowest possible cost. Value engineering is a methodology that ensures the owner is not over-paying for quality when an equally effective, less expensive option exists. Product quality remains the ultimate goal.

Step by Step Methodology

Value engineering is a team sport. A group of project stakeholders—including architects, designers, estimators, engineers, contractors and project leads—is involved to score the best product possible. The Society of American Value Engineers International (SAVE International) defines value engineering as a "function-oriented, systematic, team approach to provide value in a product, system, or service."

Value engineering is not just a concept; it's a methodology. Whether a team wants to substitute one material or system for another, consider alternative building methods or limit environmental impact, the process of value engineering remains generally consistent.

Step No. 1: Information Gathering

Identify the material makeup and scope of a project. This step is all about collecting data and getting a clear understanding of the project. Materials, schedule, costs, drawings and specifications are studied until the team is familiar with the project concept, who will be using the end product and what the expectations entail. Once you know what you're dealing with, you can begin to talk function.

Step No. 2: Function Analysis

Analyze the functions of the elements identified in the previous step and evaluate their necessity to the goals of the project. There are two forms of functions; "primary functions," vital to the existence of the final product, and "secondary functions," notable but not critical to the core of the project. Once these are identified, the team can get creative and investigate solutions.

Step No. 3: Creative Speculation

Develop alternative solutions for delivering necessary building functions. The value engineering team brainstorms to generate potential design solutions to reach the project functions. It's smart to focus on the big-ticket items because they have the most opportunity to deliver value. At this stage of the game, no viable options are eliminated, even those with serious flaws. Next, designers and their teammates will eliminate the weak plays to present only their strongest options on game day.

Step No. 4: Evaluation

Assess the alternative solutions. By turning to subject matter experts and questioning the available options, the team can begin weighing alternatives against one another. The primary focus of this discussion should be how well each alternative can perform the function of the original solution. The evaluation may include where the facility will be built, how it will be used and the weather in the area. The details matter.

Owner expectations matter too, so those must be discussed. Delivering value is tremendous but if the facility does not do what the owner intends and the vision is unexecuted, the team has missed the mark. Remember that every choice has consequences. A change in one area of a facility can affect any or all other areas of the facility. The team must discuss the holistic effects of every alternative.

Step No. 5: Cost Analysis

Allocate costs to the alternative solutions. The team needs to answer two important questions: How much will the solution cost today? And how much will it cost over the facility's life cycle?

The design team's best tool in this step of the process is accurate construction cost data. Historical pricing is great for a rough projection of costs for known materials, equipment and tasks, but it may prove inadequate in the value engineering process.

Project estimates need to be detailed down to the assembly or unit costs. To help get to this level and assess feasible alternative solutions, many architects, owners, engineers and other construction professionals rely on accurate cost data from a reliable industry expert. RSMeans data from Gordian is a highly-trusted, detailed, localized and accurate construction cost database. Such a robust resource is ideal for value engineering because it contains tens of thousands of viable alternatives.

Input from the maintenance team and life cycle cost products will help answer how much the alternative solution will cost over the long-term. This step will likely conclude with three options to choose from: the original design, one that costs a little more now and less later and another that costs a little less now and more later.

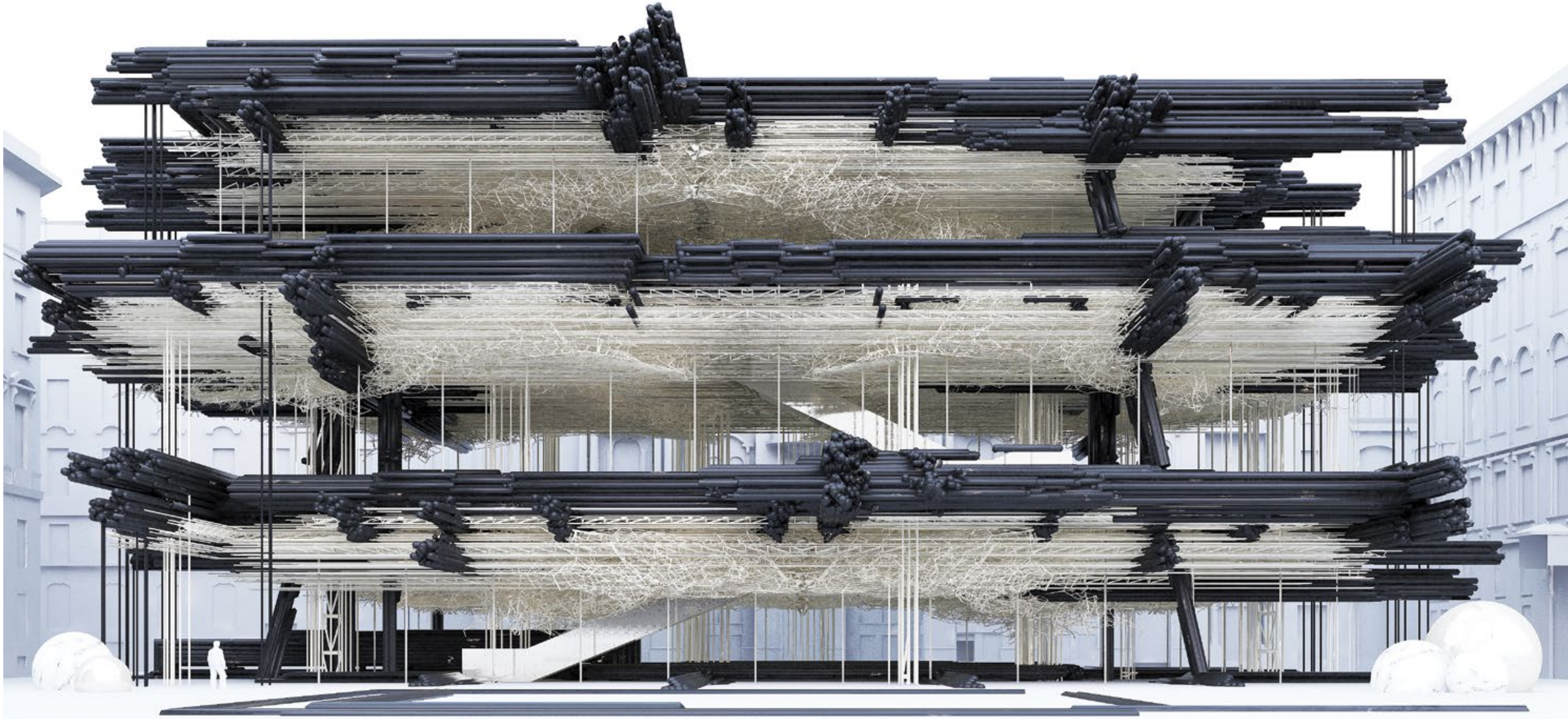
Step No. 6: Development

Develop the alternatives with the highest likelihood of success. Project timeline and available resources will influence the actions taken during this step. The team may create sketches, digital square foot models, verify cost estimates and/or validate other decisions during this time. At the very least, the team needs to assemble all recommendations, their advantages and disadvantages and implementation plans to present to project owners.

A Trusted Process

Since Lawrence Miles introduced the method to his team at General Electric, value engineering has been a process that seeks to maximize budget without sacrificing quality. 70 years later, Miles' method has been refined and adopted by industries outside of engineering. Today, the process is still trusted by design teams to build trusting client relationships and help project owners make the most of their resources.

Find out how RSMeans data from Gordian can add value to your next project.



Excessive Resolution

Designers meet the second coming of artificial intelligence.

BY MARIO CARPO

Designers have been using computer-based tools for design and fabrication for almost one generation. In the course of the last 30 years we have learned that computers can help us draw and build new forms of unprecedented complexity, and we have also discovered that, using CAD-CAM technologies, we can mass-produce variations at no extra cost: that is already history—the history of the first digital turn in architecture. Today, however, more and more powerful computational

Linear hexagonal strands define a series of thick volumeteric strata in Hextrata, designed by Gilles Retsin Architecture for a Vienna art museum extension.

WanderYards, designed by Daniel Koehler and Bartlett UCL students (left) shows how shifts of combinatorial granularity enable diversity through repetition of simple space samples. VoxelChair v1.0 (right), designed by Manuel Jiménez Garcia and Gilles Retsin of Bartlett UCL Design Computation Lab, is a prototype chair using new design software for robotic 3-D printing.

IMAGES: COURTESY DANIEL KOEHLER, BARTLETT UCL (TOP); MANUEL JIMÉNEZ GARCIA, BARTLETT UCL (BOTTOM)

tools can do way more than that. Computers, oddly, seem now capable of solving some design problems on their own—sometimes problems we could not solve in any other way. Twenty years ago we thought computers were machines for making things; today we find out they are even more indispensable as machines for thinking. That's one reason why many, including many design professionals, are now so excited about Artificial Intelligence (AI). The term itself, however, is far from new: it was already popular in the 1950s and '60s, when computer scientists thought that Artificial Intelligence should imitate the logic of the human mind—that computers should "think" in the same way we do. Today, to the contrary, it is increasingly evident that computers can solve some hitherto impervious categories of problems precisely because they follow their own, quite special, logic: a logic that is different from ours. And already it appears that this new, post-human (or, simply, nonhuman) logic vastly outsmarts ours in many cases.

The main difference between the way we think and the way computers solve problems is that our own brain was never hard-wired for big data. When we have to deal with too many facts and figures, we must inevitably drop some—or compress them into shorter notations we can more easily work with. Most classical science was a means to that end. Geometry and mathematics—calculus in particular—are stupendous data-compression technologies. They allow us to forget too many details we could never remember anyway, so we can focus on the essentials. Sorting is another trick of our trade. As we could never find one name in a random list of 1 million, we invest a lot of work in sorting that list before we use it: if the names are ordered alphabetically, for example, as in a telephone directory, we can aim directly at the name we are looking for without having to read all the names in the list, which would take forever. Yet that's exactly what computers do: since they can scan any huge sequence of letters and numbers in almost no time, they do not need to keep anything sorted in any particular order. Take alphabetic sorting as a metaphor for the way we think in general: we put things in certain places so we know where they are when we need them; we also sort things and ideas to make some sense of the world. But computers need none of that: unlike us, they can search without sorting. Computers are not in the business of investigating the meaning of life either.

Just as we could not easily deal with a random list of a million names when we look for one in particular, we could not easily work with a random heap of 1 million different bricks when we need them to build a house. In that case too, our natural aversion to big data (or to data too big to manage) drives us to some drastic simplifications. First, we standardize the bricks, so we can assume they are all the same. Then we lay them in regular rows, and we arrange all rows within simple geometric figures—most of the time, rectangles or circles drawn in plans, elevations, and sections. Thus we can forget about the physical shape and material properties of each individual brick, and we can design entire buildings by composing simpler and cleaner outlines of bigger and supposedly uniform surfaces and volumes. An individual craftsman with no blueprint to follow and no accounts to render could deal with each brick (or stone or wooden beam) on the fly and on the whim of the moment, following his talent, intuition, or inspiration—that's the way many premodern structures were built. But no modern engineer or contractor would dream of notating each brick one by one, since that would take forever, and the construction documents would be as big as the *Encyclopaedia Britannica* in print. Yet, once again, this is what computers do. Today, we can notate, calculate, and fabricate each individual brick or block of a building—one by one, to the most minute particle. If the particles are small, they can be 3-D printed

Let's leave to machines what we are not good at doing and keep for us what machines cannot do, which is plenty.

on-site. If they are bigger, they can be assembled by robotic arms. That procedure is exactly the same, and takes the same time, regardless of the regularity of the components, their number, size, and layout. Computation at that scale today already costs very little—and it will cost less and less.

The advantages of the process are evident. Micro-designing each minute particle of a building to the smallest scale available can save plenty of building material, energy, labor, and money, and can deliver buildings that are better fit to specs. Not surprisingly, buildings designed and built that way may also look somewhat unusual. And rightly so, as the astounding degree of resolution they show is the outward and visible form of an inner, invisible logic at play that is no longer the logic of our mind. Perhaps human workers could still work that way—given unlimited time and money. But no human mind could think that way, because no human mind could take in, and take on, that much information. Each to its trade: let's leave to machines what we are not good at doing and keep for us what machines cannot do, which is plenty.

Machines search—big data is for them. We sort: compressing data (losing or disregarding some in the process) is for us. With comparison, selection, formalization, generalization, and abstraction come choice, meaning, value, and ideology, but also argument and dialogue. Regardless of any metaphysical implications, no machine-learning system can optimize all parameters of a design process at the same time; that choice is still the designer's. Fears of the competition coming from Artificial Intelligence today may be as misleading as the fear of the competition coming from industrial mass-production was 100 years ago. But, just as coping with the mechanical way of making was the challenge of industrial design in the 20th century, coping with the computer's way of thinking is going to be the challenge of postindustrial design in the 21st century, because today's thinking machines defy and contradict the organic logic of the human mind, just as the mechanical machines of the industrial revolution defied and contradicted the organic logic of the human body. ■

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