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INFRASTRUCTURE
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By McKinsey & Company

Voices on Infrastructure

Scaling modular construction

September 2019

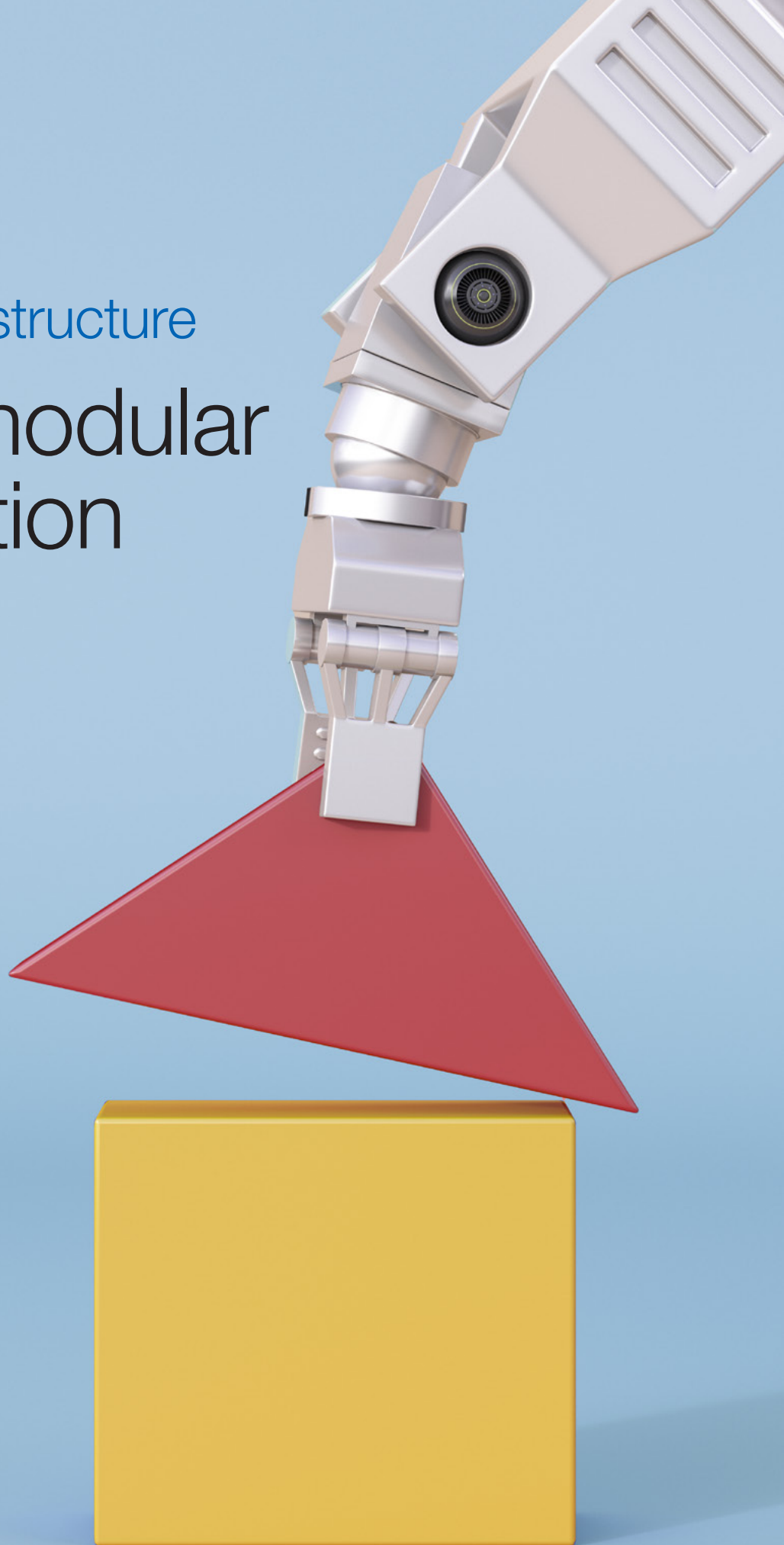




Table of contents

02	Introduction
03	News from the Global Infrastructure Initiative
06	Global lessons to enable modular construction to take root
18	Working together to tackle the UK housing crisis
22	Breaking the mold: The construction players of the future
26	Changing the game: A conversation with Kattera's Michael Marks
30	Pivoting to modular construction: An interview with Mark Skender
34	Achieving affordable modular housing: An interview with Ambar's Bruno Balbinot
06	Expert insights: What are three tangible drivers needed to scale modular construction, and how big could it grow?
38	Modular construction: Priorities for real-estate developers
42	Digital twins: Taking modular construction to the next level

Introduction



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Welcome to the September issue of *Voices*, a collection of insights on **scaling modular construction**. Modular construction has experienced popularity in the past, but a new wave of attention could indicate the trend is finally here to stay if it achieves stable footing and scale.

McKinsey research finds that by 2030, the productivity benefits of prefabrication could [save Europe and the United States \\$22 billion annually](#). This issue of *Voices* examines perspectives from across the value chain on how to realize those industry-wide benefits. All stakeholders will need to act: real-estate developers must “productize” and adapt, public-sector leaders must thoughtfully encourage modern methods of building, and construction players must start to rethink their long-term strategic positions.

For parts of the industry, modular construction is poised to fundamentally alter the way we build—and in doing so, it will likely create new winners and losers across the ecosystem. We hope you find this issue of *Voices* insightful, and we welcome your thoughts. 🗣️

News from the Global Infrastructure Initiative




Tony Hansen

Director of the Global Infrastructure Initiative,
McKinsey & Company

Welcome to our September 2019 edition of *Voices*, exploring the theme of scaling modular construction. Modular construction is experiencing a new wave of innovation and investment, as discussed in our report, [Modular construction: From projects to products](#). In this edition, we discuss what it will take for the construction industry to go beyond modular, optimize the mix of new solutions, and collectively shape the projects of the future.

We have a busy schedule of Global Infrastructure Initiative roundtables in the latter part of 2019. In early September, we hosted a [roundtable in Sydney](#) on “**Preparing for Australia’s next wave of infrastructure delivery**.” More than 40 Australian industry leaders participated in spirited discussions, and we invite you to read our [recap](#). In Washington, DC, we hosted a roundtable on “**Creating the right urban infrastructure for shared, seamless autonomy**” and, consistent with this issue, one on “**Modular construction: From projects to products**” in Chicago. For the rest of this year, we have roundtables scheduled in San Francisco, Johannesburg, Milan, and Houston. Visit our [roundtable](#) and [innovation site visit](#) pages to see past and future events.

Last year, we announced that GII had convened a cross-sector industry working group in North America to accelerate the adoption of digital technologies across the construction value chain. This volunteer effort has made significant progress, and the Construction Digital Transformation Association (CDTA) has launched as a nonprofit with ten founding organizations. The CDTA members are actively working on driving industry change and are inviting public and private asset owners to join the group. Members have already begun sharing learnings and establishing mechanisms to investigate data trusts and project piloting. Interested parties should contact [Keven Brough](#).

Looking ahead, our December issue will cover the topic of “**The workforce of the future**.” We hope you enjoy this edition of *Voices*, and we welcome your thoughts on any of our GII programs. If you have comments or would like to subscribe a colleague to *Voices*, please contact us at info@giiconnect.com. 



Global lessons to enable modular construction to take root

A look at countries that have embraced modular construction reveals that two critical conditions—labor dynamics and housing demand—predict adoption, though other factors can also play a big role.



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The popularity of modular construction—be it in the form of 2-D panels that require on-site assembly or fully constructed 3-D units built in off-site factories—varies widely in different countries and regions around the world. In some places, such as the United States, adoption remains nascent, while in others, such as Scandinavia and Japan, modular construction has penetrated the market.

Our research has found that seven factors determine the attractiveness of a market for modular construction (Exhibit 1). The leading factors are labor dynamics—specifically construction labor shortages—and continuously high housing demand. After these, determining factors include local site constraints, supply chain and logistics, quality

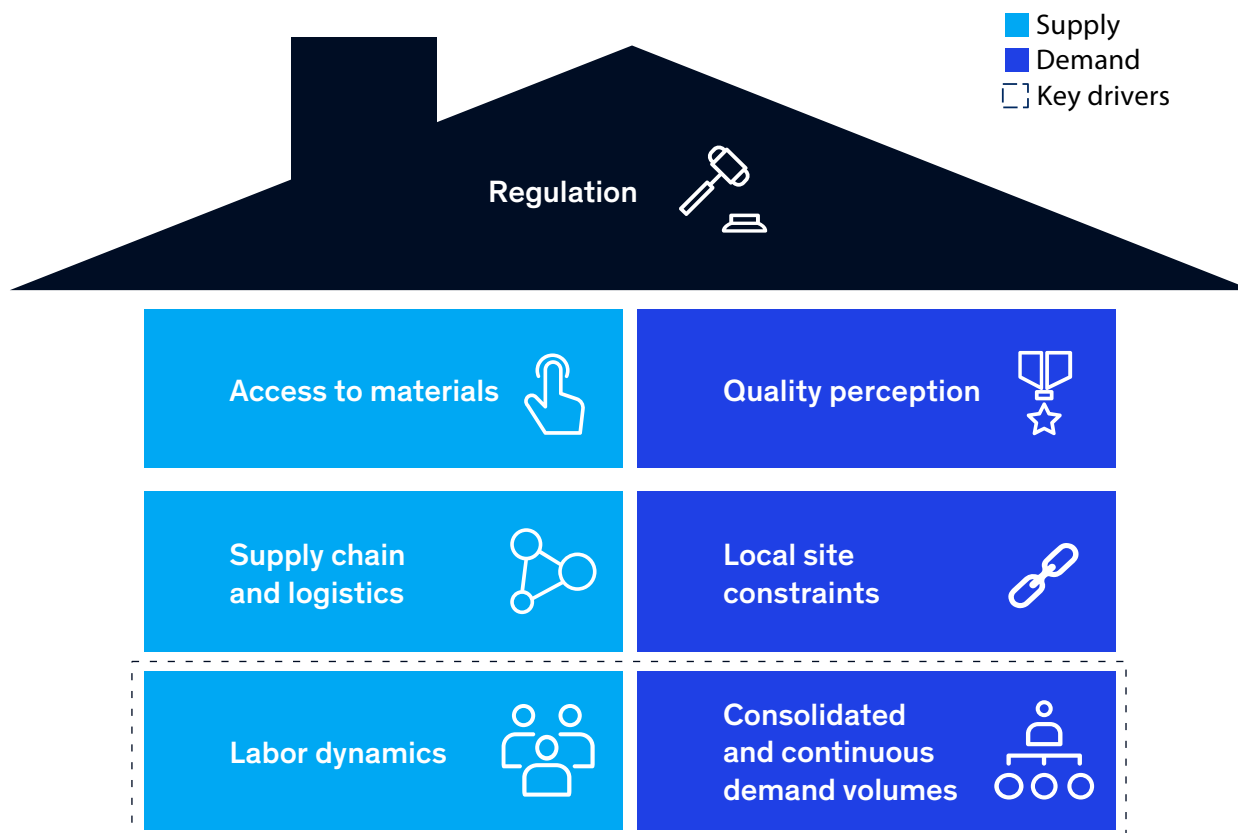
perception, access to materials, and regulations. A brief look at the leaders and the laggards around the globe reveals the conditions that enable modular construction to thrive.

The role of quality perception in holding back modular construction in the United Kingdom and United States

Modular construction has had mixed fortunes in the United Kingdom and the United States. After World War II, both countries underwent modular housing booms thanks to rebuilding efforts, the need for social housing, and a desire to make use of empty wartime factories. However, demand evened out in the United States in the 1950s due to the reputation of this type of construction as

Exhibit 1

Seven factors determine the attractiveness of a market for modular.



poor quality and unsafe, a perception confirmed by the 1968 collapse of the Ronan Point tower in East London. Its use in the construction of social housing also contributed to a poor societal image, and it fell out of favor as developers pursued more traditional construction methods.

Modular is starting to lose its negative image and is now experiencing a resurgence in popularity. This is thanks, in part, to the opportunities it offers for fast and cost-effective construction, against a backdrop of housing and labor shortages; the United Kingdom alone needs to build 300,000 new homes each year to meet existing levels of demand. Shifts in the offering have also contributed to its resurgence. Modular construction no longer involves simply stacking precast concrete panels into monotonous structures; rather, it allows for more varied offerings featuring high-quality designs and materials.

Why Japan and Scandinavia embrace modular construction

While the need for housing and rising labor costs made Japan ripe for the adoption of modular construction, other factors were in play that have contributed to it becoming a mainstream construction method. In addition to developers capitalizing on synergies with the country's strong manufacturing industries to ensure economies of scale and lower production costs, a counterintuitive environmental factor has helped to drive its popularity: the elevated risk of earthquakes in the region. The enhanced seismic performance of modular homes often results in them selling at a premium compared with homes built using traditional construction methods. Another key enabler is related to regulations; Japan has embraced the use of industry-specific inspectors for modular construction rather than a general building code.

Modular construction is also proving to be a popular construction method in Scandinavian countries. Again, housing demand and high labor

costs are two of the drivers behind its adoption, but an additional factor is local site constraints: cold weather and short daylight hours limit the time available on site. As such, modular construction—which replaces time spent on-site with time building under a factory roof—is a logical alternative to traditional construction. A further factor that has spurred the adoption of modular in the Nordics is convenient access to materials. A number of companies operate in rural areas close to timber supplies.

Increasing modular adoption around the world

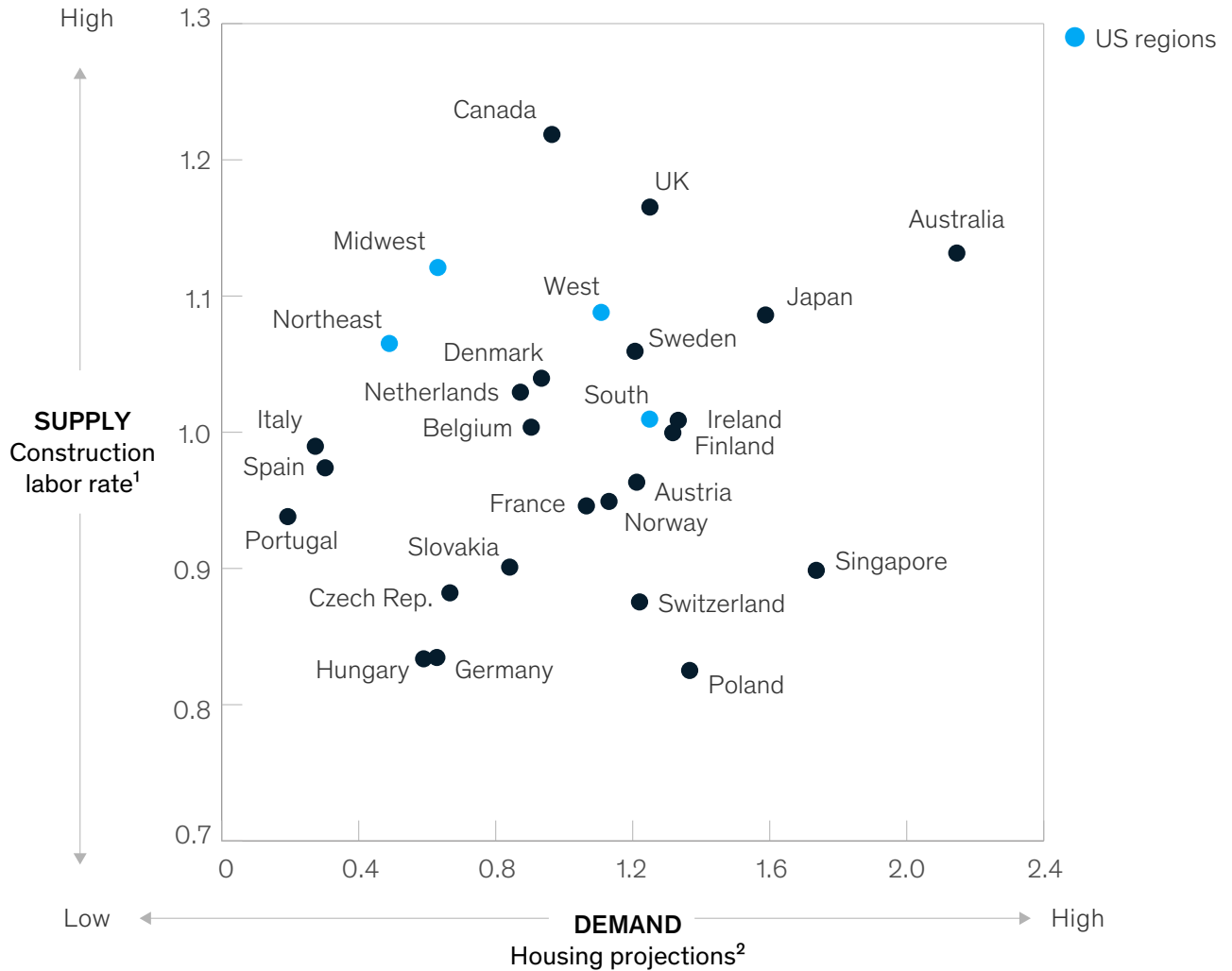
As we look at the intersection again of the two main drivers of modular construction—labor cost and housing need—Australia, Singapore, the Southeast United Kingdom, and parts of the US West Coast appear among the biggest opportunities for growth (Exhibit 2). Today, each of these markets exhibits different levels of penetration, and the success of the transition to modular approaches will depend first and foremost on how competition and industry dynamics play out—but also on how the other five external factors are handled in a given geography. For example, modular construction can compress construction time by up to 50 percent, and lower net construction costs combined with decreased overall life cycle costs can yield up to 20 percent savings. But more complex supply chains and logistics—such as transport regulations limiting the size of modules that can be transported by road—can increase the total cost of a project by 10 percent. Still, if executed properly, the potential benefits are significant, and are expected to become more reliable as the industry progresses.

Favorable regulatory frameworks can play a big role in driving adoption of modular construction. In Singapore, for instance, all public housing must be built using modular techniques, despite the relatively high availability of labor to meet the housing demand. Building standards and financial incentives can also be used to drive adoption of modular construction around the world.

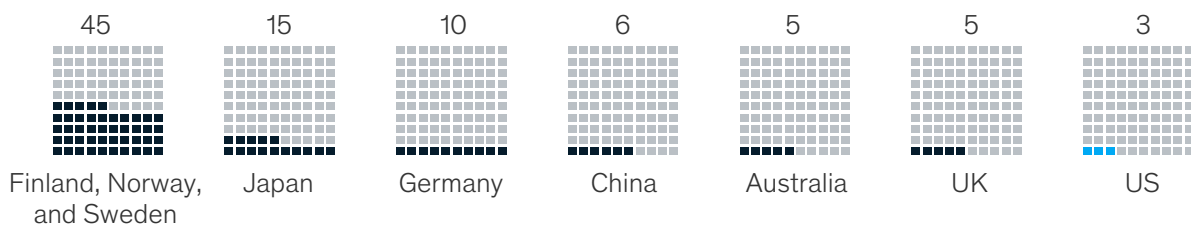
Exhibit 2

Many countries exhibit conditions appropriate for growth in offsite construction, and some markets are already established.

Near-term demand for new housing vs construction labor supply



Current offsite share of housing, %



¹Construction wage divided by national median wage.

²2017–20 average housing projection as a % of national housing stock

Source: 5 in 5 Modular Growth Initiative (Ryan Smith); ABS.Stat; CMCH; curbed.com; Euroconstruct; HIA Australia; ILOSTAT; interviews; Ministry of International Trade and Industry (Japan); Mitsui Fudosan; Natural Resources Canada; OECD; Prefab Housing (Matthew Aitchison); Roland Berger; UK Ministry of Housing; Urban Redevelopment Authority; US Census Bureau; McKinsey Capital Projects & Infrastructure



Early adopters of modular construction will likely be the construction leaders of tomorrow, driven by several circumstances. For one, smart building technology will increase the labor demand of construction per unit, and greater design complexity will require modular approaches to secure building quality and congestion. In addition, sustainability restrictions will tighten construction-site regulations regarding duration; transport quantities; or light, noise, and dust emissions. As modular players continue to gain credibility and scale, we expect modular construction to revitalize and help to finally push construction productivity to new heights. To get there, government leaders, developers, investors, and others around the world will need to take stock of the factors that determine the path modular construction takes to scale. ■

This article is based on a recent McKinsey report, “Modular construction: From projects to products,” June 2019.

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Working together to tackle the UK housing crisis

Encouraging UK governments and construction companies to scale modern methods of construction can help address concerns over diminishing housing as well as prepare the emerging workforce to manage it.



Nick Walkley

Chief executive officer
Homes England

The UK housing crisis is well documented—especially in the most unaffordable areas—and it is rightly considered the country’s top domestic priority. In 2018, housebuilding reached its highest level in more than 20 years, but this still falls significantly short of the numbers required to solve the fundamental supply-side challenge. To address the issue, the UK government has set a target of 300,000 homes constructed per year by the mid-2020s.

Reaching this goal will require a 40 percent increase in the current construction workforce headcount—that is, if the industry continues to rely on traditional construction methods.¹ In addition, to reach that housing target, construction needs to be one of the most productive sectors in the United Kingdom. However, UK construction productivity has stagnated since 2008.² In short, the government can’t reach its target if the industry continues to operate the way it has for decades.

Modern methods of construction (MMC)—a broad term encompassing a range of volume-manufacturing and technology-enabled techniques—has the potential to be significantly more productive than traditional site-based construction processes. Because of its ability to create round-the-clock off-site production, MMC can be carried out with a notably reduced (and alternatively skilled) workforce, providing a much-needed productivity boost amid the industry’s existing skilled labor shortage. Furthermore, MMC creates the chance to improve the quality and energy efficiency of homes, as well as increase the safety of building sites.

One of Homes England’s strategic priorities as the government’s housing accelerator is to improve construction productivity, encourage developers to use MMC, and increase the capacity of the off-site manufacturing industry. While MMC is relatively nascent today, we believe it is the future of housebuilding in England.

Unequivocally, no group can achieve the changes needed to build the homes the country needs alone. For MMC to help create the seismic shift the industry needs, construction leaders must collaborate within and outside the industry to demonstrate the potential of MMC. Only then can the country’s affordable-housing needs be met, necessary skills developed, and adoption hastened.

How collaboration can scale modern methods of construction

The UK housing crisis has burgeoned over decades, but the solution needs to be realized much faster. There are two fundamental requirements for increasing penetration and reach of MMC and thus improving the sector’s productivity.

Quantify the opportunity

The construction industry is taking notice of MMC and starting to ramp up production: Goldman Sachs’s £75 million investment into TopHat is testament to this. Innovators such as Vision Modular are creating a new way to build vertically at pace—ideal for the emerging build-to-rent sector, with companies such as Greystar and Tipi using the system. Major housebuilders, including Berkeley Modular and Countryside, have also recognized that their ambitions cannot be met through traditional methods alone. Both are vertically integrating MMC factories into their supply chains.

But as some are beginning to explore MMC, the scale of the opportunity is yet largely unknown. The United Kingdom has a long way to go compared with the MMC pioneers in Germany, Japan, and Scandinavia. In part, this lag is because of first-mover resistance as well as the lack of clear research about how new building methods perform against their traditional counterparts. Thus, one of the industry’s first efforts is proving that MMC could solve the country’s needs.

Homes England is in a unique position of both supporting an industry with a massively shrunken

supplier base and disrupting it through MMC. Striking balance between the two requires careful partnering and planning.

Gateshead Innovation Village, a research initiative by Home Group, analyzes the benefits of different types of MMC versus traditional build techniques. This demonstrator project—which Homes England supports through our Shared Ownership and Affordable Homes Programme—tests various innovative building methods to understand how they work and where they can be used. This is a starting point for giving the industry confidence in new construction methods.

Building on the work at Gateshead Innovation Village, and as part of our objective to improve construction productivity, Homes England will be launching an MMC pilot site-research program. It will monitor and report on up to 25 sites, all of which are using ambitious forms of MMC to build new housing. We will then benchmark these sites against traditional build approaches to provide the industry with the data to make informed decisions about emerging technologies.

Develop new skills

The current lack of traditional construction skills provides the backdrop for transitioning to increased dependency on MMC in the industry. In addition to traditional construction skills such as carpentry, stonemasonry, and roofing, the skills needed for MMC to reach scale include digital manufacturing, engineering, and design. As the next generation of built-environment professionals seeks out creative, tech-enabled careers, this rising reliance on innovative tools and high-quality design could help construction gain renewed appeal.

Still, the construction industry needs to proactively ensure it creates such a pipeline of workers. For example, Berkeley Modular is working with a local college to create apprenticeships that develop skills specifically

for MMC.³ The modular manufacturer has committed to recruiting ten apprentices from the college annually, with the goal of building construction experience among young graduates and exposing them to new methods of manufacturing-style construction.



To scale modular construction, it is clear that collaboration will be key.

In May 2019, Japan’s biggest housebuilder and MMC expert, Sekisui House, announced its move into the UK housing market after striking a £90 million deal. The deal will see it work with Homes England and Urban Splash to deliver thousands of new homes across the country. As part of the deal, Sekisui House has invested £22 million of new equity; through the Home Building Fund, Homes England is investing another £30 million of equity and debt funding.

The plan now is for Sekisui House and Urban Splash’s “House” development business to partner to build thousands of homes in the United Kingdom using the latest modular construction techniques. This investment is a clear statement of intent from a global housebuilder and a disruptive entrant to the UK market.

When Homes England launched in 2018, we set out to disrupt the housing market to accelerate the pace of construction. By helping bring one of the world’s largest and most innovative housebuilders to UK shores, we’re doing just that. However, at their current rate, the strides being made in MMC will not solve the housing crisis—even as such innovation, investment, and change emerge.

Local governments, builders, and manufacturers need to openly and willingly engage to discuss the basic issues through roundtables and

conferences. They can then look at specific sectors to learn best practices and share experiences. The industry must start working toward these goals now to increase construction productivity and meet the growing housing need in the United Kingdom and beyond. ■

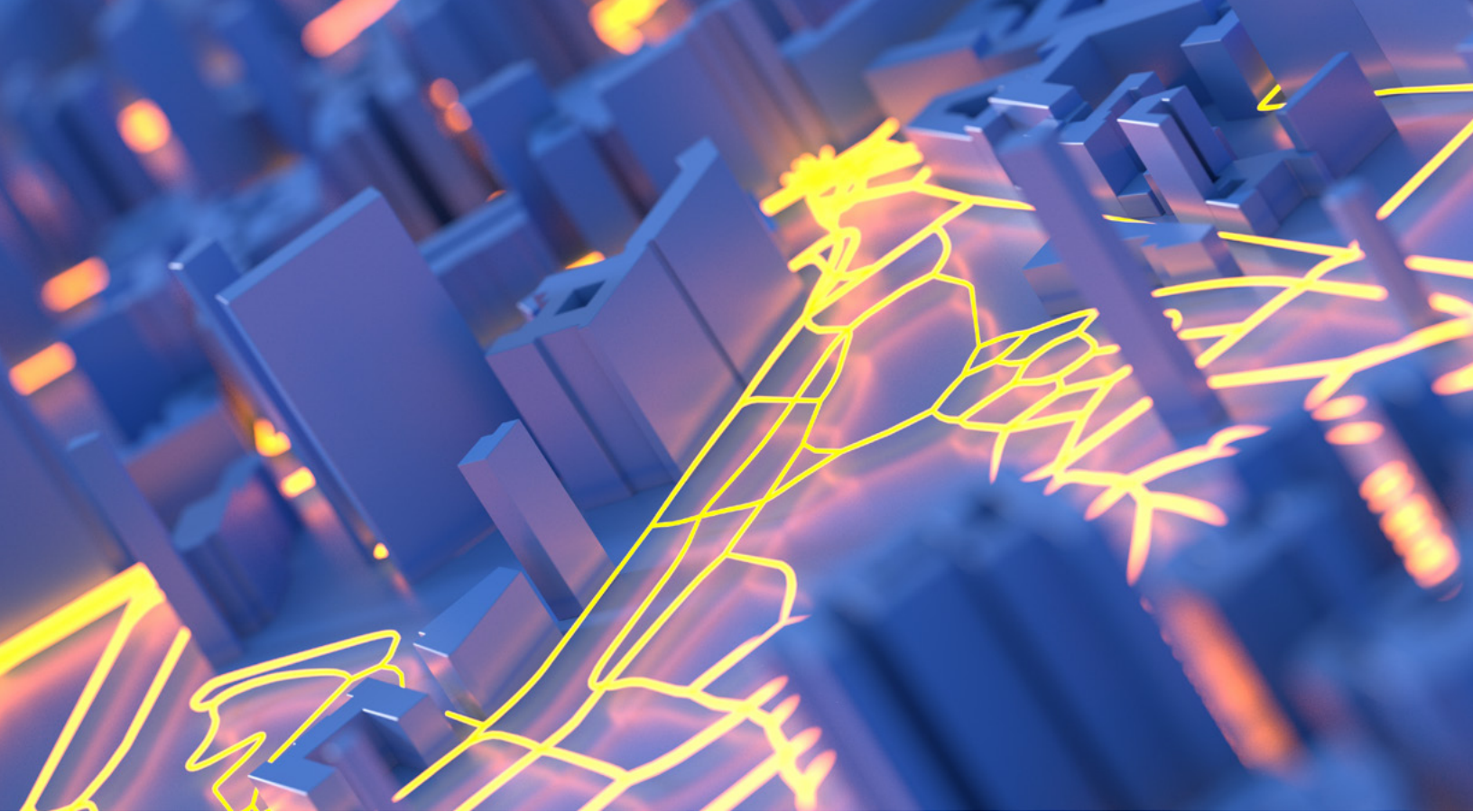
¹ *The impact of modern methods of construction on skills requirements for housing*, Construction Industry Training Board and Whole Life Consultants, April 2019, citb.co.uk.

² Productivity dropped 2.5 percent annually; *Statistics on trade and productivity of particular industries, 2008 to 2016*, March 1, 2019, Office of National Statistics, ons.gov.uk.

³ “North Kent College and Berkeley Modular to create unique apprenticeship opportunity,” Berkeley Group, September 3, 2018, berkeleygroup.co.uk.

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Breaking the mold: The construction players of the future

The engineering and construction industry, long berated for lagging behind in terms of digitalization, is picking up steam. New business models are changing the game.



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Digital technologies have transformed industries, from automotive to transportation to banking. Even agriculture, which has historically been slow to transform, has taken a huge leap toward digitalization.¹ For a long time, the engineering and construction (E&C) industry was seen as less vulnerable to disruption. Industry fragmentation, a one-off approach to design-and-build projects, and a ready supply of manual labor kept the need for productivity improvement below that of other industries. This is changing fast: incumbents, new entrants, and investors alike are realizing the potential of technology to accelerate projects, reduce costs, and improve safety in a \$10-trillion-a-year industry.

Contributing 13 percent of global GDP, construction is the largest industry in the world—and is primed to unlock significant value through productivity improvements. We already see new archetypes of successful players emerging, seeking to capture those benefits. Now is the time for E&C companies to make bold decisions on how and where to play in this exciting era.

How disruption in engineering and construction is playing out

The disruption of the E&C industry is exemplified by five movements:

- ***Unprecedented (and ever-growing) flows of capital into engineering and construction technology.*** From 2013 to 2018, investors poured \$18 billion into E&C technology, compared with \$9 billion over the previous five years.² We expect growth to continue accelerating; for example, in August 2019, Brick & Mortar Ventures announced a \$97.2 million construction-technology fund focused on design, construction, and operations and maintenance.
- ***A blossoming field of new technologies fueled by start-ups.***³ Hundreds of start-ups throughout the supply chain have emerged, greatly accelerating the development of technologies such as digital twins, 3-D printing, augmented and virtual reality, machine learning, and lidar. These new technologies also include an expanded range of data platforms for E&C or supply chain information, such as is available through Schindler's BuildingMinds and YTwo Formative. Such start-ups will have an impact on every aspect of E&C, from materials to contracts to design and simulation.⁴
- ***Corporate, large-scale tech M&A.*** Today, E&C technology M&A is nearing a five-year high, led by industry leaders such as Autodesk (BuildingConnected and PlanGrid), Oracle (Aconex and Textura), ProCore (Honest Buildings), and Trimble (e-Builder and Viewpoint). Much of this M&A represents horizontal growth, as the barrier is lower than going vertical due to the large and diverse customer base of the E&C industry. Done right, this M&A can simplify digital processes by eliminating the need for project stakeholders to navigate multiple software systems, as may otherwise happen when dealing with multiple applications at different stages.
- ***Public-sector demand for technology adoption, especially 4-D and 5-D building-information modelling (BIM).*** While there is still significant room for the public sector to provide incentives for E&C technology adoption, some governments are taking action to spur innovation on public projects.⁵ For instance, the UK government now requires level-two BIM and a preference for vendors that offer off-site construction. Deutsche Bahn, a German railway company, has introduced 5-D BIM solutions over the past five years.
- ***New technology companies showing growing interest in the engineering and construction market.*** For example, the Alphabet subsidiary Sidewalk Labs has entered the developer market, while Amazon is pursuing a role in the building-materials distribution market.⁶

Technological advancement alone is not causing disruption

There are broader factors at play in the disruption of the industry besides the new wave of technologies.

- *Many developed economies are facing skills shortages*, with E&C companies struggling to find skilled workers. At the same time, demand is growing, particularly in housing. For example, the United Kingdom needs about 300,000 new homes a year, underpinning demand for new building methods such as modular.⁷
- *Fast-evolving owner and customer needs*, which make future-proofing harder. Customers and other stakeholders are increasingly demanding flexibility of space (as exemplified by the likes of WeWork), lower-carbon construction, and smart infrastructure, for example.
- *Pressure on traditional engineering and construction company business models*, which are prone to lower margins and unforeseen issues such as write-offs. This pressure can raise the stakes on strategic bets, such as diversifying into services and development or taking on debt. When these strategic bets businesses fail, they create ripples throughout the economy. For example, several recent failures of major contractors in the United Kingdom have put large public projects at risk.
- *The prospect of slowing economic growth*, which will increase pressure to better manage costs and fluctuating demand.

New engineering and construction archetypes are emerging

All these developments are helping the industry unlock some of the \$1.6 trillion of productivity gains that we identified in our 2016 report.⁸ In fact, first movers are already saving money,

compressing schedules, and lowering asset lifecycle expenses.⁹

Despite the encouraging signs, much work remains to fulfill this enormous potential. Many firms are still in “pilot purgatory” and have not achieved any a significant competitive edge. Even some bold companies never make it past the pilot phase. Some companies are unable to launch their productivity programs at scale and struggle to establish organizational capabilities and governance, develop a data and analytics technology blueprint, or improve data quality and data life cycle management processes.

Players are experimenting with new archetypes to move forward and seize the rapidly expanding value (see box, “Emerging engineering and construction industry archetypes”). These archetypes contrast with the traditional models of architect, engineer, specialist contractor, and design-and-build contractor. They are illustrative, and while there will be variants, the key question for incumbents is whether the traditional models will survive alongside the new archetypes—and, if so, in what form?



Disruption in the E&C industry is no longer coming—it is here. New E&C archetypes are emerging, but it is not clear how the industry will look in the future and what companies will win. What is clear is that the opportunity to capture value through gains in productivity are enormous, and incumbents and start-ups alike should consider where and how they can capture a slice of that value. ■

⁷ For more on the gains being made in agriculture, see Sara Boettiger and Sunil Sanghvi, “How digital innovation is transforming agriculture: Lessons from India,” May 2019, McKinsey.com; David Fiocco, Liz Harrison, and Candace Lun Plotkin, “Cultivating the omnichannel farmer,” February 2019, McKinsey.com; Kevin Laczowski, Asutosh Padhi, Niranjana Rajagopal, and Paolo Sandrone, “How OEMs can seize the high-tech future in agriculture and construction,” March 2018, McKinsey.com.

Emerging engineering and construction industry archetypes

- **Platform integrators.** They provide the platforms to design and manage large assets across their life cycle. These platforms include tools such as generative design, 5-D BIM, and digital twins to optimize the asset in design, construction, and operation. Examples of platform integrators include Autodesk, Procore, and Trimble.
- **Vertically integrated designers and manufacturers.** These companies own the design and specification and full fabrication and assembly processes. This enables them to create modular solutions at scale to reduce the cost base and accelerate E&C. Examples of vertically integrated designers and manufacturers include Katterra and the “design-to-make” concept by Autodesk.
- **Lean executors.** These players are close to traditional trade contractors. They run simulations and plan best practices to quickly and safely execute projects. Logistics and on-site materials are managed using digital tools to reduce waste and optimize for just-in-time delivery. Examples of lean executors include Bechtel and Kiewit.
- **Job-site solutions and equipment suppliers.** These tech companies are all about increasing productivity on the construction site. Often, they will start as small start-ups that provide equipment and planning and tracking tools for specific trades; some scale to become bigger players. Examples of job-site solutions and equipment suppliers include Hilti, Qualis Flow, and United Rentals.
- **Tier-1 or tier-2 material suppliers.** These specialists design and fabricate building products and subsystems, such as prefabricated mechanical and electrical risers or integrated plumbing products. They optimize design for assembly to minimize time on-site. Geberit is an example of such a material supplier.

² Jose Luis Blanco, Andrew Mullin, Kaustubh Pandya, Matthew Parsons, and Maria João Ribeirinho, “Seizing opportunity in today’s construction technology ecosystem,” September 2018, McKinsey.com.

³ Jose Luis Blanco, Steffen Fuchs, Matthew Parsons, and Maria João Ribeirinho, “Artificial intelligence: Construction technology’s next frontier,” April 2018, McKinsey.com.

⁴ Blanco, Mullin, Pandya, Parsons, and Ribeirinho, “Seizing opportunity in today’s construction technology ecosystem,” McKinsey.com.

⁵ Jose Luis Blanco, Thomas Dohrmann, JP Julien, Jonathan Law, and Robert Palter, “Governments can lead construction into the digital era,” April 2019, McKinsey.com.

⁶ For more on Sidewalk Labs, see Dan Doctoroff, “Dan Doctoroff on how we’ll realize the promise of urban innovation,” January 2018, McKinsey.com.

⁷ Nick Bertram, Steffen Fuchs, Jan Mischke, Robert Palter, Gernot Strube, and Jonathan Woetzel, *Modular construction: From projects to products*, June 2019, McKinsey.com.

⁸ Filipe Barbosa, Jonathan Woetzel, Jan Mischke, Maria João Ribeirinho, Mukund Sridhar, Matthew Parsons, Nick Bertram, and Stephanie Brown, *Reinventing construction through a productivity revolution*, McKinsey Global Institute, February 2017, McKinsey.com.

⁹ Jan Koeleman, Maria João Ribeirinho, David Rockhill, Erik Sjödin, and Gernot Strube, “Decoding digital transformation in construction,” August 2019, McKinsey.com.

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Image courtesy of Katerra

Changing the game: A conversation with Katerra's Michael Marks

As Katerra strives to digitally disrupt the construction industry and “productize” the way we build, CEO Michael Marks discusses lessons learned and aspirations.



Michael Marks

CEO and founder
Katerra

Katerra has made the news with its unorthodox approach to construction and backing from investment firms. Believing that the construction industry was long overdue for disruption, co-founder and CEO Michael Marks set about integrating tech, design, manufacturing, and construction to make building projects faster and less expensive. With a focus on selling products as well as end-to-end services, the company is challenging convention while also finding its way in a historically under-digitized industry.

McKinsey: *As the former CEO and then chairman of Flextronics, you are bridging Silicon Valley and the construction industry. Until quite recently, that was an unlikely pairing. What has surprised you as you've gained ground in construction?*

Michael Marks: I've been surprised by how long things take. It's a two-year cycle from an initial bid on a project to completion. Coming from an electronics background, where the cycle is measured in hours, the construction project duration is something that's hard to get used to. And there are several influencing factors when it comes to the length of projects, including the fact that there are many unknowns in construction—weather, for one, and land use. Forecasting in this business is much more difficult than what I've experienced in the past, so the uncertainties also contribute to how long things take.

Coming from outside the industry has its own challenges. In the beginning, we didn't have enough people who knew how to build—and those who did thought differently than we did. We each needed to navigate a fundamentally new way of doing things. So we acquired some general contractors, which gave us local knowledge of pre-established processes and expertise. We then bridged the gaps between traditional construction and our mind-

set and approach, focusing on highly efficient mass production using our own supply chain and manufacturing.

The future of construction and our approach to it require a bifurcated skill set. We still need carpenters, electricians, plumbers, and the traditional skills and roles, but because we're also approaching construction as a product, we have to train those people specifically for that approach. That whole process alone takes two to three years.

Of course, as an experienced entrepreneur, I know that no business ends up looking the way you thought it would when you started, and we're going through that now. The good news is we have all the tools we need in place, and we're now concentrating on execution and bringing Katerra to a strong competitive position.

McKinsey: *You mentioned a few acquisitions; can you expand on how M&A has informed Katerra's strategy?*

Marks: I think of acquisition as acquiring talent. We have a significant pipeline, so clearly we need people to do this work. We can't do that one person at a time, so we're building our talent through acquisitions and truly integrating these companies into Katerra. We now have more than 7,500 employees globally, up from 2,800 a year ago. One of the challenges in acquisitions—in any company or industry—is that they can be disruptive as you attempt to meld the cultures of a handful of companies. Our approach is to make sure senior people at these companies are on board with our approach and vision before we make any acquisitions. We want crews and team members to be energized by the integration. We've found some top talent gems that way—moves that we wish we'd made a year earlier.

Once we've made the acquisition, additional moves support our strategy, operations, and business model. Given the low levels of digitalization and IT spending in construction, most companies' IT, finance, and HR systems are lagging behind. We're addressing that in two ways. First, there are the basics of getting people on Katerra's email system and having robust servers and security systems. Second, is launching our software platform, which links every stage of a project and the building supply chain. That's a bigger project and something really new in the industry, and it's one of the things I'm most excited about.

McKinsey: *In addition to addressing those legacy systems, what else is top of mind when it comes to priorities?*

Marks: One is the widening trade-skills gap. There's already a huge shortage, something like 200,000 people—it's a real problem.¹ And with low numbers of young people coming into the industry, that gap will widen. That's true across the whole country and globally. Union workers are aging out and construction is experiencing a union shrinkage. This creates a larger industry void, because workers traditionally acquired skills through union apprenticeship programs. We have to do our part to keep attracting people to the industry and training them, or there will be no people to do this work. We have recently created our own apprenticeship program that responds directly to our process and business model,² including the integration of new tools and technologies.

McKinsey: *As you implement these initiatives, how do you see Katerra's business model—as both a company executing projects in the field and a product company—taking shape?*

Marks: Katerra is going to have two different ways of going to market. One is the more standard side of the general contracting business, but the

difference is that we have our own manufacturing and supply chain. We will get walls, windows, kitchens, bathrooms, and cabinets from our own factory. We will use those prefabricated pieces in the standard business, which will increase margins and create more value, but it will still look like a traditional build on the outside. And in that go-to-market approach we may perform some of the work ourselves and just use regular subcontractors, which the industry is used to.

The other part of the business is the product side, for which we're managing the products all the way from design to manufacturing. Instead of using subcontractors in this area, we're training people to do that. As I mentioned before, we have very complex, completed walls and floors that come from the factory—with built-in mechanical, electrical, and plumbing engineering. So, much of the high value-add is getting everything done in the factory and through an assembly process in the field.

Those are the two different paths, and they complement each other. Interestingly enough, we are rapidly increasing our sales of materials to other general contractors.

McKinsey: *Overall, the interest in "productizing" construction is growing. What's your take on the conversation?*

Marks: People are definitely reacting—and not just to us. Prefab building is getting more and more attention, primarily from hospitality and healthcare because those buildings are very reproducible. More companies are turning their attention to disrupting this industry and there's more discussion about our approach—and that's a good thing.

People are asking about competition. I come from electronics—a highly competitive industry and a \$1.3 trillion market—and construction is six times the market size. Competition is good for the industry:

suppliers will begin to change the way they design things, and there will be more support for the workforce. The more people who are engaged, the more the industry will change. And that's good for everybody. In an \$8 trillion market, there's plenty of room for innovation.

This is a never-ending process, and the industry is poised to evolve. Soon enough we'll be putting up buildings in a month, or a week, and at way lower cost because we're going to just keep engineering these processes. The factory will get more efficient and we'll automate certain factory tasks. Just think about cell phones—the iPhone is ten years old, and it does all kinds of things that nobody ever imagined when the first one came out. Innovation is relentless, and there are new capabilities every year—and that's exactly what's going to happen with buildings. ■

¹ Procore Technologies, "Making up for the construction labor shortage with technology," *Construction Dive*, June 5, 2019, [constructiondive.com](https://www.constructiondive.com).

² "Kattera Launches Apprenticeship Program," *Professional Builder*, June 25, 2019, [probuilder.com](https://www.probuilder.com).

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Pivoting to modular construction: An interview with Mark Skender

Achieving a fully integrated modular construction offering relies on pragmatic leadership and a people-first culture.



Mark Skender

Chief executive officer
Skender

Chicago-based building company Skender was already long established when CEO Mark Skender presented a new vision for the organization: integrating design, manufacturing, and construction to move modular projects from concept to completion. Only two short years later, Skender offers factory-produced and steel-structured three-flats that can be erected in just 90 days. In addition, these buildings are constructed in Skender's 105,000-square-foot factory located on Chicago's predominantly underserved southwest side,¹ with the goal of promoting progress in both housing and the local workforce.

In this interview, Mark Skender talks about his company's vision for modular construction, the importance of assembling the right team, and how vertical integration can help reinvent the structure of the industry.

McKinsey: *The construction industry is grappling with a number of disruptive factors, such as innovations in technology. Do you think incumbents are too entrenched for change to happen?*

Mark Skender: I think a lot of the investment in construction technology is good, but it's still a Band-Aid on some of the industry's fundamental flaws. There are signs that we're heading toward this type of technological disruption, but companies that have gained recognition and made headlines are still in the very early stages. There's still a lot of "wait and see" happening as to whether integrating tech solutions into modular construction will be successful.

It's difficult to say what construction will look like ten years from now—the industry is so large and fragmented. Each project is treated as singular and bespoke, which creates inefficiencies and limits the scalability of research and development.

There will certainly be significant movements in some vertical markets, probably by newer, more agile players that will have the courage to ignore convention and find opportunities for growth. What our company has done is look beyond the single project and ask ourselves, "Well, how could we improve the whole model if we were to look at it from a longer-term perspective?" In many ways, that led us to where we are.

McKinsey: *When did you start to think about delving into modular construction? How did you initially go about it?*

Skender: We first embraced lean construction principles—namely eliminating waste and striving for continuous improvement—14 years ago. Not many people talked about lean construction then, and it took us years of commitment to adapt. That period gave us the confidence to tackle something we knew was important, even if our customers weren't asking for it. It also gave our leadership team the space to shift focus to the future without needing to fight fires in the present.

Then, probably five years ago, I started researching modular construction. There was no boilerplate or blueprint for how to do something like this, so we did the research on our own. We realized that the key elements to make a venture like this successful are leadership and culture.

McKinsey: *How did you decide to pivot the organization to a vertically integrated model, and how did you manage to do so in just two years?*

Skender: As we were aligning on a vision, I had actually just read McKinsey's 2017 report identifying seven levers for improving construction productivity.² We scheduled an off-site meeting, where I told the leadership

team, “Look, let’s go into this off-site. Let’s address each of the seven areas and come up with both a reasonable and a more ambitious idea for each.” As a result, in November of 2017, we had a bold and compelling vision for the future. And that vision immediately empowered us to move forward and make deliberate decisions.

The ability to move quickly was grounded by a culture that put people first, followed by lean principles triggered by a compelling vision of the future. A lot of things are exciting, in particular, about having a significant and positive impact on both affordable housing and the workforce. To that end, we put our factory on the southwest side of Chicago, and we’re recruiting a workforce from underserved areas of the city. Not only is the business strategy behind this decision compelling, but the social aspect of it is also very energizing. It taps into the deeper meaning of what we’re doing.

McKinsey: *Getting everyone aligned around a vision is sometimes easier said than done. How did you approach that?*

Skender: When I was drafting this vision document, I built a case with a series of “whereas” statements that essentially characterized our industry and our position in it. The goal was laying out some fundamental reasons for moving in this direction. One of those reasons was, “Whereas the industry has not improved productivity in decades.” The next was, “Whereas our position in the industry is a fee-based general contractor, we are facing tightening of fees without a corresponding decrease in risk.” The third was, “Whereas our culture of innovation and employee engagement allows us to be agile.” Laying out the rationale was important.

That approach helped us think differently, evolve, and align everyone. First, we brought in design—so

we could design the building. And then it became, “If we see a building as a product, we can totally flip our paradigm of how we think about ourselves and the industry.” There have been several iterations and improvements of that vision statement in the past two years that were informed by the new talent and leadership we’ve brought on.

One thing I’ve learned is that the two- to three-year strategic plan is dead. The industry is moving and changing much more rapidly than that. Our vision allowed us to have a long-term destination, but now we segment our strategies into six-to-nine-month periods because our ideas can change. We’re heading down a path that has no blueprint, so we’re creating as we go.

McKinsey: *Were there moments of doubt or days when you felt stuck? How did you handle those?*

Skender: We envisioned that engineering, design, construction, and manufacturing would all come from the same company. Tim Swanson came on as chief design officer, we bought a design firm, and we started a manufacturing company from scratch. We thought, “OK, then we’ll be able to solve all these industry problems.” But the reality is that the early stages weren’t easy. We got stuck a lot. Even when you’re committed to changing things, adjusting industry-ingrained behaviors and processes takes time.

So we said, “All right, if we’re thinking about a product, let’s reach outside our industry and look at how a company like Ford Motor Company would get its design, engineering, manufacturing, and sales and marketing teams together when they design their new products.” Reaching outside the industry to look at a process can help solve challenges in how these teams work together in this new business model. It’s still a work in progress, but we’re taking advantage of opportunities to learn.

McKinsey: *What do you think the construction industry will look like five years down the road if modular construction has the impact you think it will have?*

Skender: I would expect construction to reduce its fragmentation, maybe through strategic alliances with some existing players or through acquisitions. When we first studied the modular industry, fragmentation had already been in the conversation for a long time. The topic ebbs and flows, and highly fragmented companies would go out of business, which didn't make me very optimistic. So what's the difference between them and us? They were trying to place an unsophisticated modular manufacturer into a commercial, fragmented endeavor, so they encountered the same industry constraints.

If the modular industry is expected to take hold and be the growth opportunity it could be, then the players will need to take a holistic and vertically integrated approach. Otherwise you're applying a modular solution to a still dysfunctional structure. ■

¹ Zach Mortice, "Can this Chicago apartment factory make new homes affordable?," *CityLab*, July 8, 2019, citylab.com.

² For more, see "Reinventing construction through a productivity revolution," McKinsey Global Institute, February 2017, McKinsey.com.

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Image courtesy of Ambar

Achieving affordable modular housing: An interview with Ambar's Bruno Balbinot

Bruno Balbinot's background in the automotive industry informs his view of the construction landscape and how modular can meet a growing need.



Bruno Balbinot

Founder and CEO
Ambar

The global housing need is significant and growing. So too is the need for affordable housing. In this interview, Bruno Balbinot, founder and CEO of Ambar, a Brazilian construction technology company (or, construtech) with a focus on efficient construction and smart housing, talks about his journey from the automotive industry to modular residential construction. He highlights some of the lessons he believes can transfer from automotive to help the construction industry increase its productivity and bring affordable housing to those who need it.

McKinsey: What led you from the auto industry to modular construction?

Bruno Balbinot: I got my start in my family's business, which partners with Volkswagen Commercial Vehicles in Latin America to develop, manufacture, and commercialize special products. These include vehicles for the military and for transporting beverages, waste, and concrete. I looked around and realized there are a lot of other industries where I could apply what I'd learned in the automotive sector. By 2012, I felt compelled to build my own company.

I quickly fell in love with construction, specifically in the residential market, because I could tell there was a major demand for affordable housing. I'd venture that 70 percent of the global demand in the residential market is classified as affordable, and every developing country is launching affordable housing programs.

The affordable housing market in Brazil, for example, remained strong even through the country's recent economic crisis. The market here is huge, and its consumer base is going to grow from 60 million families in 2010 to 90 million by 2030.¹ For every single family, you're going to need a new house—there's no substitute for a family home in today's society.

I also realized how archaic the homebuilding industry is: low productivity and little transparency result in high costs, waste, and delay. These inefficiencies, coupled with the scope of the opportunity, make homebuilding a very interesting industry to disrupt.

When you look at the construction industry, every housing project seems unique. Meanwhile, since the same car is made millions of times, it is assembled with standardized components, enabling higher productivity. But one of our key findings is that if you're looking at Southeast Asia or North America, you find huge patterns when you break down a family home into its components: the kitchens, the bathrooms, and so on. So at Ambar, we break down nonstandard projects into a family of standard components, thus bringing efficiencies to the industry and enabling modular and digitalization.

McKinsey: Describe how you think of homes and cars in terms of products, components, and materials.

Balbinot: When you look at the automotive industry, the product is the car. The components consist of all the different parts used to assemble a car: engines, gear boxes, axles. And then you have materials—aluminum, steel, plastic—that are used to manufacture those components. Other industries see a similar value chain. A mobile phone (the product) is made of a screen, semiconductor, and casing (the components), which are made of aluminum, glass, et cetera (the materials).

But when you look to the construction industry, the components part of the value chain doesn't exist. Instead, raw materials are being transformed at construction sites into the final product. This reality comes with consequences: a lot of waste is generated on construction sites, and the labor is intensely specialized.

McKinsey: *What are some of the key differences between automotive and construction?*

Balbinot: I see two big differences in terms of technology and supply chains. Construction is maybe 30 years behind the automotive industry in terms of technology. For example, the automotive industry used to draw all of the components and the cars on paper. Between the '80s and '90s, they moved to software. And then in the late '90s, they moved to computer-aided technology, which basically converts 2-D to 3-D and also connects the design to the bill of materials, of the components, and of the car.

But in the construction industry, building-information modeling (BIM) is still not in widespread use. In Brazil, just 7 percent of construction companies are currently using BIM, and more than half of companies believe that 3-D design is the same as BIM—which of course is not the case.² The lack of precise planning technology brings a lot of inefficiency to the rest of the value chain because projects aren't tightly connected from the design phase to the construction phase.

The second major difference between the automotive and construction industries is their supply chains. The automotive industry's supply chain includes materials and labor, allowing a manufacturer to look beyond the cost of each product at the big picture. In construction, however, material and labor are handled separately and by subcontractors. As a result, construction companies focus on up-front costs for materials and labor rather than the total cost of construction. Since modular construction comes with more material expenses but much lower subcontractor expenses—and therefore much lower labor expenses—its cost structure is much more predictable and streamlined.

All that requires construction companies to shift their mind-set. It requires them to change the way they work, the way they design, the way they procure, the way they run construction sites. The ecosystem now is much more open than it was when we started. The industry is paying significant attention to all these new things. But we're not fully there yet.

McKinsey: *What opportunities does the industry have to bring modular affordable housing to developing markets?*

Balbinot: Modular affordable housing can reduce the total cost of construction through better productivity and quality, thus making affordable homes available to more people. In addition, modular construction can reduce the environmental footprint of projects by significantly reducing waste through more efficient use of materials in a controlled environment. With traditional construction, usually about 30 percent of all the material delivered to sites becomes waste. By combining modular or off-site construction with BIM, estimates are more precise and construction-site waste is close to zero.

McKinsey: *How does modular construction improve energy efficiency?*

Balbinot: We apply the same vision to energy efficiency as we do to cost efficiency—using technology to improve people's lives. We ran a two-year pilot in Brazil with almost 200 families. We looked at how much families pay for their mortgages and in energy and water bills. The total cost of ownership (TCO) was the sum of those three major components.

We looked at it with these questions in mind: if we build a home with a solar photovoltaic and a smart-home device, how much will the mortgage go up? And

how much will the water and energy bills go down? We are not only looking for better TCO but also delivering technology so families can manage their energy consumption, empowering them to make better decisions.

We learned that today in Brazil if you build an affordable home as I described, the mortgage will go up R\$39 (\$10) and the energy bill will go down R\$90. So the monthly TCO of that home is R\$60 lower than a traditional home. On a yearly basis, you're talking about R\$700, which is almost half of the monthly income of the average family living in affordable housing. The home will cost less from a total cost of ownership perspective, and the quality is higher.

McKinsey: *How will the modular construction landscape change in the next five years? And how can we encourage more entrepreneurship in construction?*

Balbinot: Developers are increasingly willing to take a chance on this new vision. It's common sense. Nobody discusses anymore *if* modular, *if* prefabrication, will be a reality or not. It *is* reality; this is happening. Everybody understands that there's no way that they can go forward if they don't buy into modular construction and BIM.

I think the upcoming five years will be amazing for modular construction. The industry is moving. I think people now are listening because the results speak for themselves and drive adoption. In our work, we've been able to reduce total cost, waste, and time on a project while increasing simplicity and transparency. As a result, we see repeat clients, have zero churn, and have generated referrals by word-of-mouth.

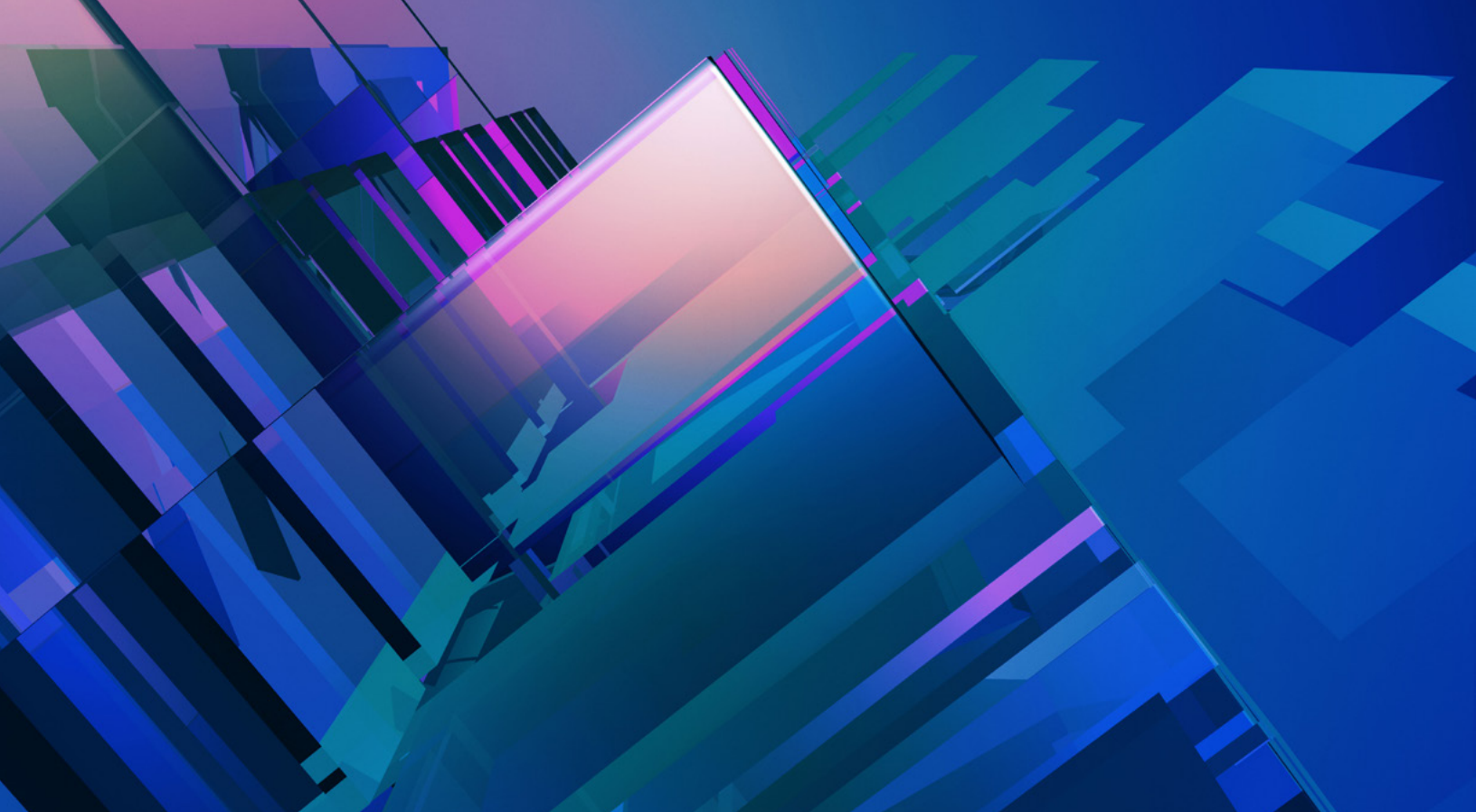
To unlock entrepreneurship, it is, of course, important to see such success stories. Three years

ago, "construtech" wasn't a word in this market. Now, it's the local word for what we do. So, I think the atmosphere of venture capital is booming, and it's paying a lot of attention to the sectors with new technologies. Construtech is a huge market and such a dynamic platform. There are so many things to be done, and people want to do them. They believe the future has arrived. I think it's a great moment for the industry.

¹ Mercado de incorporação imobiliária brasileiro: Potencialidades do mercado habitacional, Ernst & Young, 2017, abrainc.org.br.

² "Setor público avança na contratação de empreendimentos em BIM," Sinaenco, August 15, 2019, sinaenco.com.br.

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Expert insights: What are three tangible drivers needed to scale modular construction, and how big could it grow?

As modular construction gains traction, industry leaders weigh in to identify common patterns and obstacles to overcome.



Kez Taylor

CEO
ALEC

By 2050, the world's population will be nearly 10 billion, up from 7.7 billion today.¹ Coupled with urbanization, population growth is resulting in more people moving to and staying in cities. In fact, by 2050, 70 percent of the world's population will be living in urban environments. This shift has created new demands for construction that the industry is currently unprepared to meet. The United Kingdom alone has an annual housing shortage of 300,000 homes.

¹"Current world population," Worldometers, accessed July 19, 2019, worldometers.info

The construction industry has an opportunity to meet the growing need by becoming product driven and more efficient—both possible through modular construction.

Increased productivity through automation and technology. We are facing a global shortage of construction skills as younger workers choose alternative professions. Modular units can help fill that gap. They can be manufactured in factories with efficient automated processes, thereby enabling high volumes of quality products to be delivered at speed and requiring fewer skilled workers. And using technologies such as building information modeling, the product is fully designed before manufacturing commences.

Effective partnerships. Global technology providers with alternative industry experiences are stepping into the construction sector, providing momentum and funding. Companies that already have extensive logistics networks with established supply chains, such as IKEA and Toyota, are bringing different but applicable thinking to modular manufacturing. A partnership between existing manufacturing or construction organizations and developers could effectively deliver modular products at scale.

Capacity to deliver a desirable, cost-effective, quality product. Large capital investment is required up front to establish a modular production facility; in order to make this investment feasible, a pipeline of secured work should be in place. The best way to secure this work is to ensure a high-quality product. Modular products should be well-designed, sustainable, energy efficient, and well-suited to every aspect of urban living for the prospective end user—this, in turn, creates demand for the products, helping achieve return on investment in the production facility.

ALEC is a multi-disciplinary construction company based in Dubai.



Thomas Gluck

Principal
GLUCK+

The modular industry is at a tipping point and poised to become a more common method of delivery. To scale modular construction in this way, the industry will have to address three factors that are currently serving as impediments to growth.

A limited pool of qualified modular manufacturers. There are simply very few qualified modular building manufacturers for noncombustible construction as well as limited experience in completing mid- to high-rise modular construction in urban environments such as New York City. This is, of course, a question of the chicken or the egg: how do manufacturers gain necessary experience while the industry is still struggling to provide a reliable delivery option for these urban environments? Despite some false starts in

the past decade, the industry is now gaining traction, so it's becoming more viable for manufacturers to invest in modular construction—and the number of qualified manufacturers will grow.

The necessity of early contracting. As cost is paramount, clients are currently forced to commit early to modular or conventional construction without the benefit of in-depth competitive bidding—thus assuming the risk of potentially unnecessary costs. Accurately comparing both methods would require two sets of full documentation, a cost-prohibitive option. In addition, because the fabrication capacities of modular builders vary, clients must engage a specific modular builder early in the design process, essentially mandating a design-build approach.

Fortunately, design-build is gaining industry traction in parallel, which will help to normalize the early awarding of architecture and construction contracts. In reality, because modular construction takes place inside controlled factory conditions, it can provide greater price assurance than conventional construction which is at the mercy of outside conditions and different subcontractors' schedules and rates. As the modular industry matures and develops a track record of comparable early pricing and final construction costs, this problem too will begin to diminish.

Lack of awareness of conventional onsite construction needs. At least 75 percent of a building's construction may be produced off-site in a factory, but a critical portion of work must still occur conventionally on-site to complete a building. Given the large geographical area served by each modular manufacturer, this work includes obtaining licenses, which requires localized knowledge. A comfort with and awareness of this type of on-site work does not currently exist in the marketplace. However, as fabricators develop experience finishing projects in various jurisdictions, and as conventional subcontractors accrue experience with modular projects, this problem will wane.

GLUCK+ is the architect-led design-build firm behind New York City's first modular steel and concrete residential building.



Joseph Schottland

Partner
Innovatus Capital
Partners

As one of the few private-equity firms already committed to modular manufacturing, we remain excited by the prospects of its acceptance across many industry sectors, but a few changes are needed for this to happen.

A shift in widely accepted business norms. The macrofactors affected by modular and its theoretical benefits are extremely compelling. However, the ingrained business norms of almost the entire construction value chain would need to be disrupted for modular to be adopted en masse.

A clear demonstration of the business value. It's a tall order, but for any disrupter, money talks. To accelerate the pace of modular adoption across industries, the primary need is to prove at commercial scale that the modular value proposition delivers on its promised benefits. Imagine if one visionary developer committed to a single factory and a secured pipeline of projects—all with the same basic design (for example, a standard hotel property). The factory could run at extremely high utilization. It would have time to adapt its supply chain and optimize its processes to a standard design and a single client. Costs would drop dramatically, and that developer would reap enormous economic benefits.

A competitive market that spurs adoption and innovation. Such a scenario would push local competitors to change their traditional approach to construction, and it would create a showcase for developers in other markets to replicate the strategy for similar gain.

The economics prevail: if a developer creates a 200- to 300-basis-point cap rate advantage, the effect is so profound that it resets the financial threshold for others to even consider participating. In that environment, would-be competitors are forced to adapt or cede that market to those that can meet the new norm. That is the embodiment of the flywheel effect of a successful disrupter.

Innovatus is an investment adviser and portfolio management firm that is invested in high-rise modular construction.



Darren Bechtel

Founder and
managing director
Brick & Mortar
Ventures



Kaustubh Pandya

Principal
Brick & Mortar
Ventures

The concept of modular construction has been in our industry for decades, but it has only recently gained significant attention from the media and investors.

Narrowing scope to build momentum and deliver projects at scale.

Instead of applying modular methods to broad construction verticals (such as heavy commercial and industrial), companies can start with simpler verticals (such as single- and multi-family homes and light commercial). Another option is to start by focusing on narrower and more manageable scopes—such as bathrooms

or medical modules—within complex verticals. Standardized methods tend to hamper design customization. As a result, we must balance the ability to deliver a product with the end customer's desire for design freedom (including placing limits on that freedom). This narrower focus also allows modular projects to be scaled at a higher velocity, taking lessons from one vertical to the next. Since doing so will need significant capital, building a compelling investment thesis will require proving the potential for returns higher than that of a private company growing at a traditional pace—for instance, potential for tenfold returns if targeting venture capital.

Incorporating complementary technology to accelerate adoption. Innovations in adjacent spaces can supercharge the pace of adoption by reducing modular-delivery cost or providing select customization at a fraction of the traditional cost. Such innovations include supply-chain tracking, utilizing materials suitable for finished-product transportation, and 3-D printing, which can provide a unique look by customizing a façade to mask an internal standard module. All of the above technologies are available today and can help scale modular projects.

Harnessing and improving existing processes and infrastructure. In addition to new technologies, modular companies can choose existing proven solutions. For example, leveraging the intermodal shipping network to reduce logistics costs for delivering prefab modules to site. The industry will also have to improve existing processes, such as permitting, for the benefits of modular construction to be fully realized.

While adoption in specific verticals will determine the scale to which modular can grow, we can safely assume at least some scope in each vertical can be made modular. Early progress will certainly be in residential and light commercial spaces.

Brick & Mortar is a venture capital firm that identifies and backs emerging technology companies in architecture, engineering, construction, and facilities management.



Roz Buick

Senior vice president
Trimble

Although modular construction has been around for decades, digital technology has evolved to a point where it can enable faster, more extensive modularization across the supply chain.

Create an empowered, high-performing supply chain. A constructible process that combines design, project management, and engineering models into a collaborative and data-rich platform would lead to greater adoption of modular construction. Inserting build-quality content and metadata into 3-D models early on enables stakeholders to accelerate modeling, increase visibility, and improve predictability across the entire project. From the designer's desk to the fabrication center, mobile devices, and robotic total stations on a jobsite, this process creates a virtuous circle of knowledge sharing that enables more effective collaboration across project teams and stakeholders.

Embrace the latest solutions. Stakeholders must continue to embrace solutions that transform the construction industry. Adopting the right software and hardware will enable smart, digital infrastructure that is designed and built using powerful work processes. Cloud platforms and technologies that harness mixed reality, such as the Internet of Things and AI, are leading to more automation. For example, modular construction companies are increasingly relying on off-site factories staffed by autonomous robots that piece together the components of a building.

Lean on historical data for continuous improvement. Having accurate data is key to driving optimization, predictability, and automation. The “secret sauce” for designers, engineers, and contractors of the future will be using historical data to draw insights from each project to continually improve processes. Ensuring real-time access to data among all stakeholders will minimize the chance for errors and enable modular projects to be built more efficiently.

By adopting a constructible process alongside digital technologies, modular construction will play an instrumental role in reducing the time to completion for construction projects of all types, positively affecting the industry as a whole.

Trimble is a provider of digital solutions across the construction lifecycle.

Voices highlights a range of perspectives by infrastructure and capital project leaders from across geographies and value chains. McKinsey & Company does not endorse the organizations who contribute to Voices or their views.

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Modular construction: Priorities for real-estate developers

Real-estate developers are in prime position to lead the shift to modular construction. Crafting their product strategies and supplier partnerships are good places to start.



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Modular construction represents the future of building development. The benefits over traditional construction should be huge: lower costs, accelerated schedules, greater predictability of both time and cost, and improved building quality. However, the modular supply chain is nascent, and benefits of the approach are largest where there is a degree of repetition well beyond individual, large projects.

Real-estate developers can be the catalysts for the transition to modular—and early movers stand to gain significantly, as they can pocket the cost savings over the traditional approach throughout the industry’s transition, until they’re forced to pass through the savings to the end customer to remain competitive. Developers must start by rethinking their product strategy with an eye toward enabling modular design—for example, by reducing the use of bespoke floor plans. From there, they can begin to build the supply chain by signing long-term partnerships with material and product suppliers.

The case for leading the charge

Real-estate developers are a natural catalyst for scaling modular construction, as they can determine how their projects are realized and by whom. The shorter timelines indicative of modular construction help to mitigate risk, as developers’ capital isn’t tied up in empty or developing land for as long. Furthermore, developers have what modular suppliers need: a forward-looking pipeline and control of the product to put through it. This position provides them with enough visibility to optimize factory operations and reduces the need to refit equipment for different projects.

Those with sizeable pipelines per product can take the biggest leap toward modularization. According to McKinsey research, a volume of about 1,000 units a year can be enough for a modular factory to break even, and a volume of 5,000 units annually allows for efficient automation.¹ Developers capable of such

scale can and should be the first ones to embark on the journey to reshape the industry—and some of them are. Berkeley Homes in the United Kingdom is building its own factory to produce 1,000 modules a year.²

Getting started

For many developers today, prefabricated elements such as bathroom pods are a matter of course. Others are new to the concept. Regardless of where they fall on the spectrum, developers that want to aggressively pursue modularization should start by creating a product strategy. Today, developers often think in terms of unique projects and opportunities. Pivoting to a “productized” mode of thinking should start with articulating the right design parameters that balance modularization at scale with the freedom to tailor each project. The approach should be based on an analysis of market segments with clear needs and growth, as well as customer research to understand the exact requirements of the targeted segments, including willingness to pay and desired customization options. Many such design customization options are readily available today through modern modular methods and building information modelling (BIM).

Developers should collaborate with designers to establish their own unique sets of product offerings—for example, specific layouts or components that best suit their target customers’ demands and can be reused over time (see sidebar, “How HB Reavis has developed a flexible office solution for midsize organizations”). The benefits of this approach are twofold: First, reusing an established design avoids rework in the design phase, facilitating scale while also meeting the needs of target customers with a known, popular product as opposed to designing from scratch. Second, investors and property owners are likely to have more confidence in a product that already resonates with the market.

How HB Reavis developed a flexible office solution for midsize organizations

The developer HB Reavis wanted to create a specific office-building product for small and medium-sized companies that seek the flexibility of coworking spaces but the privacy and branding of owned real estate. The developer conducted extensive customer interviews to identify needs and applied design thinking and virtual reality to develop and test product options, which included floorspace layout; engineering approaches to maintain flexibility in the structure; and productization of the commercial offering with simple, two-page contracts, per-workspace pricing, and guaranteed scale-up options. This product can now be rolled out across cities globally. With this scale, modularization of the entire construction process could be a next step.

Developers can work with engineers to tweak a design to make it more amenable to factory production and logistics. For example, they can explore making room types, such as kitchens and bathrooms, more repeatable to reduce factory switchovers—that is, the need to refit equipment to create different types of modules (2-D panels, 3-D rooms). They can reduce the width of building elements to facilitate road transport from the factory to the build site. They can engage local authorities to approve changes to zoning or building codes with a promise of higher efficiency and lower cost provision of housing. And they can explore what mix of 2-D and 3-D elements is most cost efficient.

Building relationships with modular suppliers will be crucial. Developers should aim to transition from operating on a project-by-project basis to forming strategic partnerships to commit a pipeline of repeatable projects over several years. They can also work with their suppliers to switch from buying materials suitable for a construction

site to those suitable for a factory. An example of this is plasterboard, which in most markets is prepared to a size that can be easily transported around a site; ordering far larger panels would reduce the amount of work required in a factory.

The next step would be to test fully modular construction on individual projects to gain experience—and trust in the chosen supplier. After that, developers can roll the product out in large numbers.

The benefits of committing at scale to a modular approach can be large. One developer identified a part of its future pipeline that was particularly suitable to a modular approach and developed a strategy to reduce construction costs. It worked closely with suppliers and committed to co-invest in and provide minimum orders for their factories. The arrangement led to cost reductions of up to 20 percent.



Developers face many challenges before modular construction can be adopted at scale. But for those willing to take the risk and disrupt the industry, the potential reward is undeniable. ■

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¹ Nick Bertram, Steffen Fuchs, Jan Mischke, Robert Palter, Gernot Strube, and Jonathan Woetzel, *Modular construction: From projects to products*, June 2019, McKinsey.com.

² Nick Myall, "Berkeley gets the go-ahead for modular homes factory," *World Architecture News*, February 2, 2018, worldarchitecturenews.com.

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Photo courtesy of Lendlease

Digital twins: Taking modular construction to the next level

Digital replicas of real-world objects can help construction companies mitigate risk and deliver more with fewer resources. Lendlease Group illustrates how this technology can be applied and scaled.



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In the past 20 years, the construction industry has fallen behind in digitalization, especially in the use of data and analytics or artificial intelligence. During Bill's time as chief digital officer of GE and Daryl's 25 years of industrial design, construction, and digital production at Lendlease, these technologies went mainstream in automotive, OEM, utilities (such as water and wastewater networks), and other industries.

Historically, construction has been a highly linear, labor-, and time-intensive process. Everything from design briefs to detailed architectural line drawings, modeling, testing, and iterative changes must be considered before a project can take shape in the physical world. And each step of the process must be communicated between the architect, engineer, and construction chains.

A “digital twin”—or digital replica of a physical entity—can aid construction projects by accelerating and automating traditional design, production, and operational processes. As such, it can serve as the backbone for prefabrication and as a more significant means for achieving industrialized efficiency.

What is a 'digital twin' and how does it complement modular construction?

Unlike traditional construction models, the digital twin replicates every detail of the original object, whether it's a high-rise or jet engine. This means the digital twin can account for the behaviors and processes involved in construction all the way down to the individual materials and components.

Take, for example, the design and construction of an offshore wind turbine. At nearly 1,000 feet tall, and with each blade measuring nearly 250 feet in length, building these turbines at sea is inherently rife with challenges. To start, a ship carrying supplies must be converted into an at-sea platform; then columns are dropped through the deck, raising the ship above water. From there, a crane is assembled on site that helps move the pieces into place.

Real-time data collected by sensors can create predictive simulations to better understand how the turbine will perform in the moment and into the future, accounting for factors such as inclement weather conditions. The sensors can also provide the capacity to input and analyze operational, environmental, and financial data to provide a comprehensive integrated solution. Real-time data can also be used to conduct a social analysis to determine how people might interact with the turbine.

These kinds of options have huge implications for prefabrication. While an alternative to on-site construction, prefabrication must still rely on some of the same circumstances: a productive factory environment to be cost effective, an automated manufacturing process (to some extent), and economies of scale based on the finely tuned repetition of uniform components. But technology can help do away with economies of scale and deliver greater supply-chain efficiency to make modular construction more feasible and profitable.

Until digital twins are successfully implemented, two additional challenges facing prefabrication will impede both investment and design. First, small projects and little to no visibility into product-to-market timing can make justifying investment hard. And second, good building design still requires understanding context and addressing issues such as environmental performance, geography, local planning, and building regulations—and these are not guaranteed.

One clear advantage of the digital twin is its capacity to align sustainability with design goals. In other words, making a digital twin can disclose its carbon footprint and energy efficiency up front. In addition, the technology means that the various pieces of a structure can be produced in an off-site factory and then assembled on site—thus buildings can be not only easily assembled but also disassembled and reused to support a circular economy.

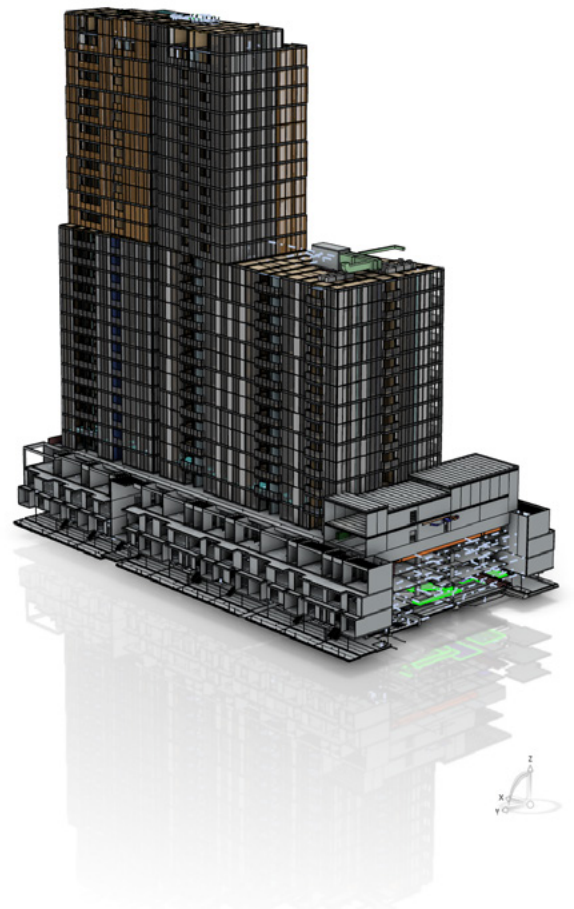
Applying digital twins to modular construction

Lendlease recently built a digital twin to test and determine the viability of building a multistory complex on Collins Wharf, located on the Yarra River in Melbourne from sustainable timber (exhibit). While this timber had been used previously, it had not been tested in buildings of this height—namely, a 28- and a 29-story apartment tower.

The inclusion of the project’s processes and materials in the digital twin identified options and produced a more granular understanding of process and cost for developers. Although it’s still early in the design process, the digital twin for the towers has already provided insight on how to actively tighten the project timeline and reduce costs.

Exhibit

The predictive capabilities of a digital twin can help determine if repurposed timber can be viable for building a high-rise apartment building.



Applying digital twins to modular construction can further help cut time and costs. For example, the Canadian technology company CadMakers successfully used digital twins to design the Brock Commons Tallwood House—an 18-story hybrid mass-timber building—at the University of British Columbia in Vancouver.

The Tallwood House provided a model to plan out the prefabrication and construction of the building that included a simulation of on-site assembly of the manufactured parts. As a result, the 20-month project was completed in under 17 months and delivered in half the time of an equivalent building using traditional methods.

Steps to scale digital twins

Digital manufacturing is already playing a major role in ending construction's reliance on economies of scale. Robotics, 3-D printing, and digitally controlled production methods are now prevalent in fabrication. These new technologies enable each component of a project to be produced locally in small volumes, cleanly and efficiently. The scope or scale of a project, basically, is no longer its defining characteristic.

The following four steps can help scale digital twins and subsequently realize the benefits of modular construction:

1. *Create high-fidelity prototypes.* Computational or generative design can be employed instead of traditional line drawings, allowing projects to free up time and costs by circumventing historically intensive design efforts.
2. *Replicate, simulate, and evaluate.* This procedure applies to both the processes for manufacturing and assembly and also the physical characteristics of the materials used. As a result, the physical performance of a component can be understood before anything is built. The digital twin can demonstrate how various manufacturing tolerances and factors can complicate the production of complex objects—for example, how buildings' components might expand, deform, or react in the real world.

3. *Make data accessible to all players.* Volumes of easily accessible data beyond the core design can be digitally stored and shared among all stakeholders and at all stages. Therefore, designers—who have traditionally been isolated from the construction and downstream manufacturing processes—are provided a collaborative approach and understanding of the project, with technical parameters firmly embedded into the design algorithm.

4. *Capture data from the physical product.* Once the project is completed and open for business, sensors can collect data to inform future designers on how the object performs. For instance, if buildings are composites of digitally fabricated components, then iterative improvements on the design of each component can be driven from this virtuous cycle. Until now, this concept has largely been absent from the architecture, engineering, and construction industry.



Ultimately, digital twins could help democratize design in construction. Although the technology is still in its early days—for both the industry and the design community—it could soon unlock the capacity to explore countless ideas using technology already at our fingertips. By prioritizing those ideas, mitigating risk, and providing efficiencies, the industry can adopt modular construction in ways previously not possible. ■

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