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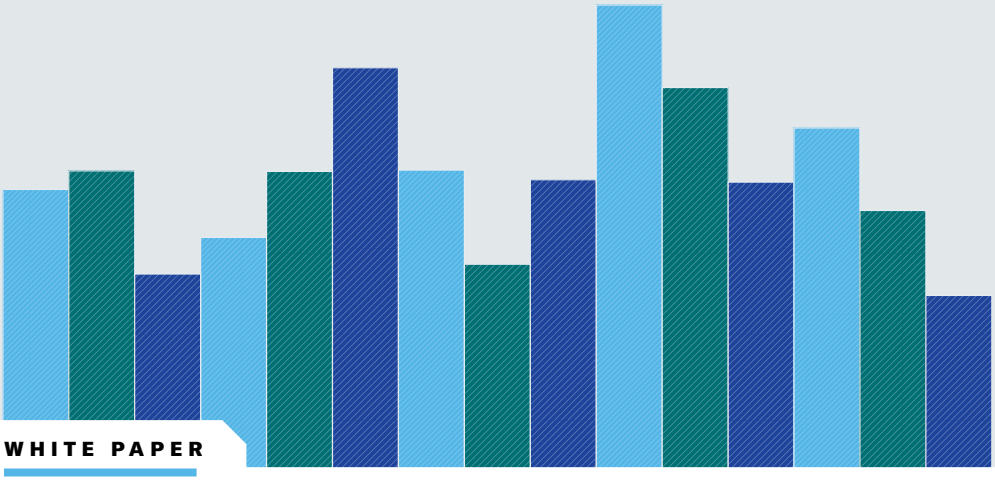

WHITE PAPER

Leveraging Artificial Intelligence and Automation for Return on Investment in Innovation

Design and Manufacturing Sector

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The Business Imperative for Automation

Mike Haley
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What stands in the way of innovation? It's often the old ways of doing things—repeating old patterns because that's what worked before. It's predictable and measurable, but it doesn't break you out of the status quo. Innovating can feel like walking on a tightrope without a safety net, but with the help of automation, it's like having an amazing mentor sitting right next to you, guiding you through new possibilities. Whether your business is architecture, infrastructure, construction, or manufacturing, automation transforms the way you work because it helps your teams explore and discover new ways of doing things.

When people ask me if automation and artificial intelligence are going to take away jobs, I always ask them, "Have we solved all the world's problems?" There are an enormous number of challenges. The architecture, engineering, and construction and manufacturing industries have low margins, face an aging workforce, and strain to adapt to new patterns of manufacturing, such as industrialized construction and reshoring of manufacturing.

Automation is your friend because it allows you to spend more time solving problems rather than focusing on tedious tasks and interpreting volumes of data. The human brain is not able to absorb the increasing deluge of data that everything—even a sensor-filled concrete beam—collects. People need computational help to see patterns and gain insight.

All that help is possible with the automation provided through digital twins, generative design, and innovative construction processes such as design for manufacture and assembly (DFMA). A digital twin—which is a dynamic, up-to-date replica of a physical asset like a car, a building, or a bridge—can absorb and exchange data throughout an asset's entire life cycle. With the addition of real-time operational data, digital twins acquire the behavioral awareness necessary to simulate, predict, and inform decisions based on real-world conditions.

With generative design, you're expressing what outcome you're looking for and letting unbiased, raw computation create, test, and evaluate options by itself. Even if you don't use exactly what comes back, this approach shows you things you weren't thinking about, triggers innovations and ideas, and helps you make informed decisions for complex design problems.

Meanwhile, DFMA—a set of design principles that helps connect the design-to-make process—is a game changer for the built environment. Through automation, you and your teams can become more productive and adaptable to change, and it can help you meet sustainability goals, including the 2021 United Nations Climate Change Conference pledge to make all buildings net zero by 2030.

All of this innovation shows the promise of automation. It's not a luxury. To solve the world's complex problems, it's absolutely essential.

Leveraging Artificial Intelligence and Automation for Return on Investment in Innovation

Design and Manufacturing Sector

Innovation capabilities are essential in today's marketplace. Forrester Research calls a tech-driven and sustainable innovation strategy "mission critical" to stave off disruption and weather continuous change—and finds that organizations that adopt this type of innovation strategy grow 2.6 times faster than those that do not adopt it.[1]

Artificial intelligence (AI) and automation are often seen as key enablers of innovation, allowing organizations to work better, faster, and more sustainably and efficiently while reducing costs. A 2021 survey of 1,843 global cross-industry organizations by McKinsey & Co.[2] showed that 87% reported a cost decrease as a result of using AI in manufacturing and 69% experienced a cost decrease in product and/or service development in 2020. Fully 63% and 70%, respectively, saw revenue increases in manufacturing and product and/or service development as a result of AI adoption in 2020.

"The business environment, whether it's supply chain or energy or climate or customer expectations, is continually changing. I think by almost that alone innovation is a necessity to ensure business growth," says John Suh, vice president, Hyundai Motor Group, and head of New Horizons Studio, a team developing an ultimate mobility vehicle (UMV) based in Fremont, Calif. "Because of change, you have to do things in new ways."

The design and manufacturing (D&M) and architecture, engineering, and construction (AEC) industries are turning to AI and automation to fuel innovation by streamlining processes, discovering new patterns and insights, and automating data-based decision making. AI and approaches such as digital twins, generative design, and design for manufacturing and assembly (DFMA) offer the potential to unleash worker creativity and move innovative activity

HIGHLIGHTS

Organizations in the manufacturing and construction ecosystems sometimes **struggle to identify and monetize innovative ideas**.

Organizations investing in the innovation required to **approach old problems in new ways enjoy greater growth**.

Artificial intelligence and approaches such as digital twins, generative design, and design for manufacturing and assembly **offer the potential to unleash worker creativity**.

beyond niche-use cases to impact the larger organization and its strategic direction.

Beyond competitive and customer pressures, factors such as sustainability and a need to attract digitally savvy younger workers are increasing the need to become more innovative to fuel future growth. But organizations in the manufacturing and construction ecosystems sometimes struggle to identify and monetize innovative ideas. Common obstacles to fostering and operationalizing innovation include cultural resistance, entrenched business practices, and uncertainty about how to instill innovation-enabling processes.

Organizations seeking to monetize innovation in the D&M and AEC industries must learn what changes they need to make to nurture and embrace innovation so they can successfully navigate tomorrow's marketplace. This transition requires understanding why innovation is so important and how innovative firms are gaining an advantage by embracing AI and related technologies. It also means increasing collaboration, identifying factors that may be holding back innovation, and leveraging the best practices that have helped early adopters in D&M and AEC transition toward innovation-nurturing business practices and cultures. Successful moves include establishing diverse, cross-functional teams and formalizing structure around innovation.

"Innovation is not just driving growth for AEC and D&M; it's somehow disrupting the industry from the bottom up," says Angelo Yu, founder and CEO of PIX Moving, a Guiyang, China-based multidisciplinary developer and manufacturer of modular smart vehicles. "Like how Henry Ford nurtured the mass adoption of cars and how Apple initiated the big bang of the digital age, innovation in design, engineering, and manufacturing will eventually change how we work, live, and play."

The Pressure to Innovate

Gartner reports that innovation requires three key elements: novelty, execution, and a useful outcome.[3] In the AEC and D&M industries, the useful outcomes of innovation include being able to sharply reduce time, cost, and risk while increasing the sustainability of construction and manufacturing processes.

Take Bryden Wood, a London-based architecture, engineering, and design company focused on innovation in the construction industry, as an example. The company is automating various AEC processes and implementing design for manufacturing and assembly, which have enabled the firm to reduce capital costs by 20% to 30%, trim schedules by 20% in many projects, and configure designs in two days that would take a traditional design team 15 months. Similarly, PIX Moving has used AI-driven design algorithms to reduce the components of a 3D-printed, autonomous-driving skateboard chassis platform to a tenth of what was needed before and apply digital fabrication to trim lead time by 75%. These are just two examples of organizations that moved more aggressively than their competitors to adopt processes, technologies, and mindsets that enable innovation and are enjoying significant benefits as a result.

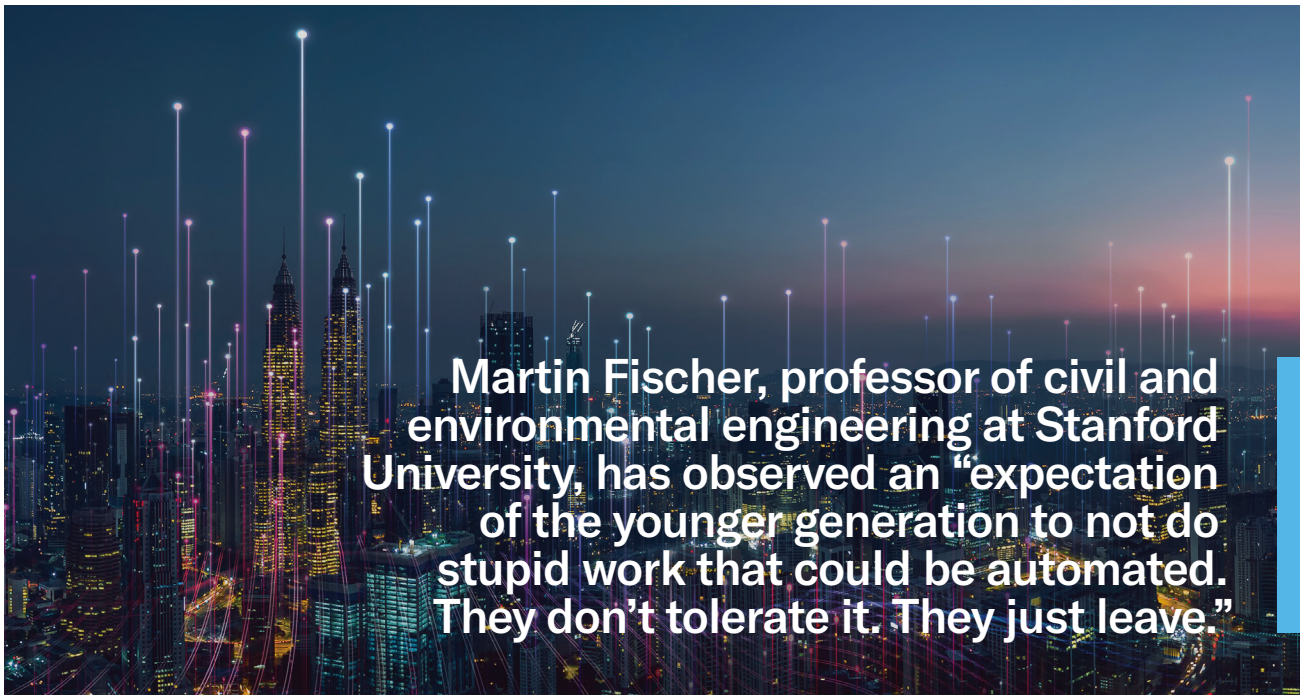
The ability to significantly reduce the resources needed to design, engineer, and build something, whether it's a scooter or a skyscraper, offers a clear competitive advantage over traditional methods. As Forrester's findings confirm, organizations investing in the innovation required to approach old problems in new ways enjoy greater growth. But signs suggest such innovative capabilities will also become a means of survival in the D&M and AEC industries. According to "Winning the Race for Survival," a May 2020 World Economic Forum white paper, "We may be on the precipice of 'Operational Darwinism,' wherein mere reductions in costs may not be enough to compete against leaders who make manufacturing a rapid and key part of their digital innovation edge." Pressure to innovate is coming from customers, competitors, and organizations' own workforces.

While competitive and customer demand are nothing new, pressure to innovate from the workforce is being felt across many industrial sectors as they struggle to attract new talent. "Everywhere in the world right now [there] is the need for more talent, better talent," says Martin Fischer, professor of civil and environmental engineering at Stanford University. Fischer has observed an "expectation of the younger generation to not do stupid work that could be automated. They don't tolerate it. They just leave."

"The 2021 Future Manufacturing Workforce Study," a survey of 882 Gen Z manufacturing employees by workforce management company UKG, found that 94% called working on fulfilling projects important, very important, or extremely important to their job satisfaction. Three-quarters agreed, somewhat agreed, or strongly agreed that manufacturing has unfavorable working conditions.

Attempts to attract new talent to industrial organizations lead to a culture clash of sorts when established workers steeped in manufacturing expertise encounter young, digitally savvy talent without that background. "And that causes quite a lot of disconnect and cultural dysfunction in some cases where the newcomers are not easily welcomed," says Jo Geraghty, cofounder of Culture Consultancy, a London-based culture change consulting organization. Organizations need ways for new hires to learn from the experience and knowledge of long-term workers while using their data skills to update and transform processes.

Sustainability goals are also upping pressure to bring innovation to sourcing, materials, and processes, with stakeholders, including investors, customers, and employees, increasingly focused on goals beyond simply driving revenue. "There's been a growing recognition, particularly around



sustainability, that it's not acceptable now not to have some strategy of how you are going to reduce materials or increase material efficiency and other things," says Jaimie Johnston, director and head of global systems at Bryden Wood.

Mandates and incentives from governments, such as the tax incentives offered to innovate in Singapore, are also dialing up the heat. Governments from the United Kingdom to Brazil to Mexico are mandating or heavily pushing the use of building information modeling (BIM), a holistic process of creating and managing information for a built asset, typically starting with government-funded projects. Sustainability requirements are finding their way into building codes, such as California's new requirements for the use of solar panels, batteries, and electric heat pumps in some new homes and commercial buildings.[4] European Green Deal proposals include new rules to make almost all physical goods more environmentally friendly and implement stronger regulations around sustainable construction. Outcomes from the 2021 United Nations Climate Change Conference in Glasgow included a focus on achieving zero global carbon dioxide emissions by 2050, impacting both AEC and D&M organizations. For the cement and construction value chain, for example, this goal will require tripling the current pace of decarbonization. Participants in a construction industry panel convened by McKinsey & Co. at the event determined that creating a culture of innovation is a strategy key to achieving that goal.[5]

Responding to this complex web of pressures will require pronounced changes to business as usual in both AEC and D&M. To stave off disruption, weather continuous change, and achieve faster growth in these industries, organizations will need to rethink processes and culture, both internally and across their ecosystems, identifying and committing to new ways of working.

Key Levers of Innovation

Technology is proving a key enabler of innovation, applying increasingly sophisticated algorithms and models to data and automating the iteration of design choices. Sources of essential data are proliferating across manufacturing and construction, thanks to increasingly affordable sensors and cameras and the ability to collect and amass data via wireless and cellular networks and the cloud. Beyond simply digitizing existing analog processes using this data, organizations are increasingly digitalizing them—rearranging business processes by sharing and collaborating on digital information in new ways, with information at the center of this new operating model. AEC and D&M organizations are leveraging automation, AI, digital twins, generative design, and DFMA to foster innovation and create business value by streamlining processes, discovering new patterns and insights, and automating data-based decision making.

AI promises to have a profound effect on the entire global economy. McKinsey created a model simulating the potential cumulative impact of the use of AI on the world economy by 2030, including an analysis of how it could affect companies.

Nonadopters [of artificial intelligence] "might experience around a 20% decline in their cash flow from today's levels," according to a 2018 McKinsey & Co. report.

In its report, "Notes from the AI frontier: Modeling the impact of AI on the world economy," published in September 2018, McKinsey analysts found front-runners in AI adoption could double their cash flow (economic benefit captured minus associated investment and transition costs) by 2030, with a 122% cumulative change. **FIGURE 1** Nonadopters "might experience around a 20% decline in their cash flow from today's levels, assuming the same cost and revenue model as today," according to the report.

The ability to leverage AI techniques to perform tasks that normally require human intelligence—often at a scale and speed that are beyond human capability—is enabling organizations to create new ways of working across design, engineering, and production processes. PIX Moving, for example, is leveraging AI and automation to develop systems that can rapidly produce a manufacturing-ready customized product. PIX Moving's Yu says the use of AI-driven design and digital fabrication techniques leads to fewer components, shorter lead time, less dependence on the supply chain, a faster response to customization needs, and a mold-free approach, all of which reduce costs significantly for the organization.

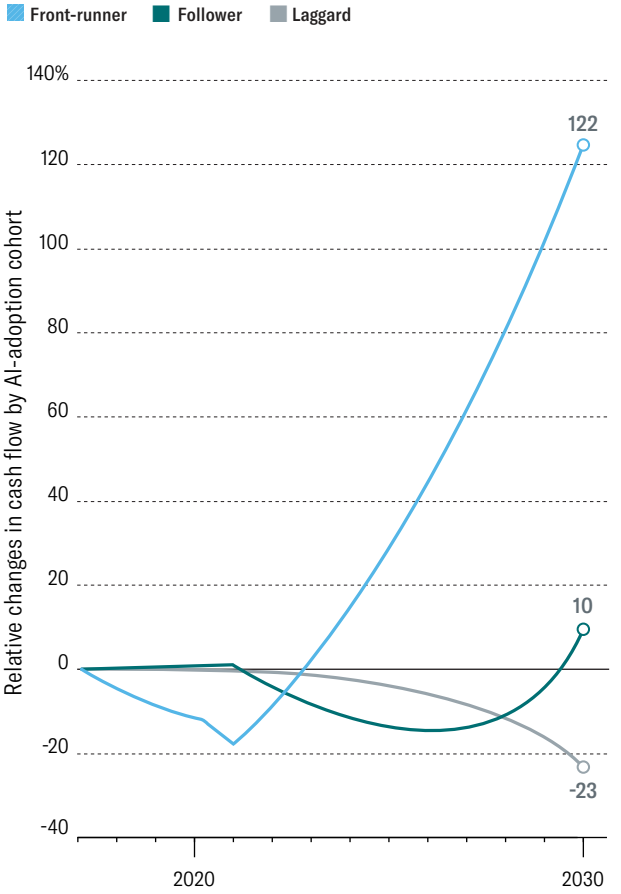
According to Yu, such software-defined manufacturing systems free PIX Moving from the factors that limit innovation for traditional automotive manufacturers. These factors include extra-large factories, heavy investment, high barriers to entry, longer lead times, and time-consuming processes, such as tooling and production line setup, which slow iteration and impose risk. When the same task—car design and production—is enabled by tools such as AI, the process "is distributed, user-participated, and decentralized, and no more molds are required, reducing tooling fixtures and [enabling us to] respond flexibly to market changes," he says.

Some of the most widely used applications of AI in construction are in progress tracking and safety. By analyzing image data captured by cameras mounted on cranes—and, increasingly, drones—construction companies are substantially reducing the many hours and people it takes

FIGURE 1

Advantages Accrue to Early Adopters

By 2030, front-runners in adopting artificial intelligence could double their cash flow



Source: McKinsey & Co., September 2018

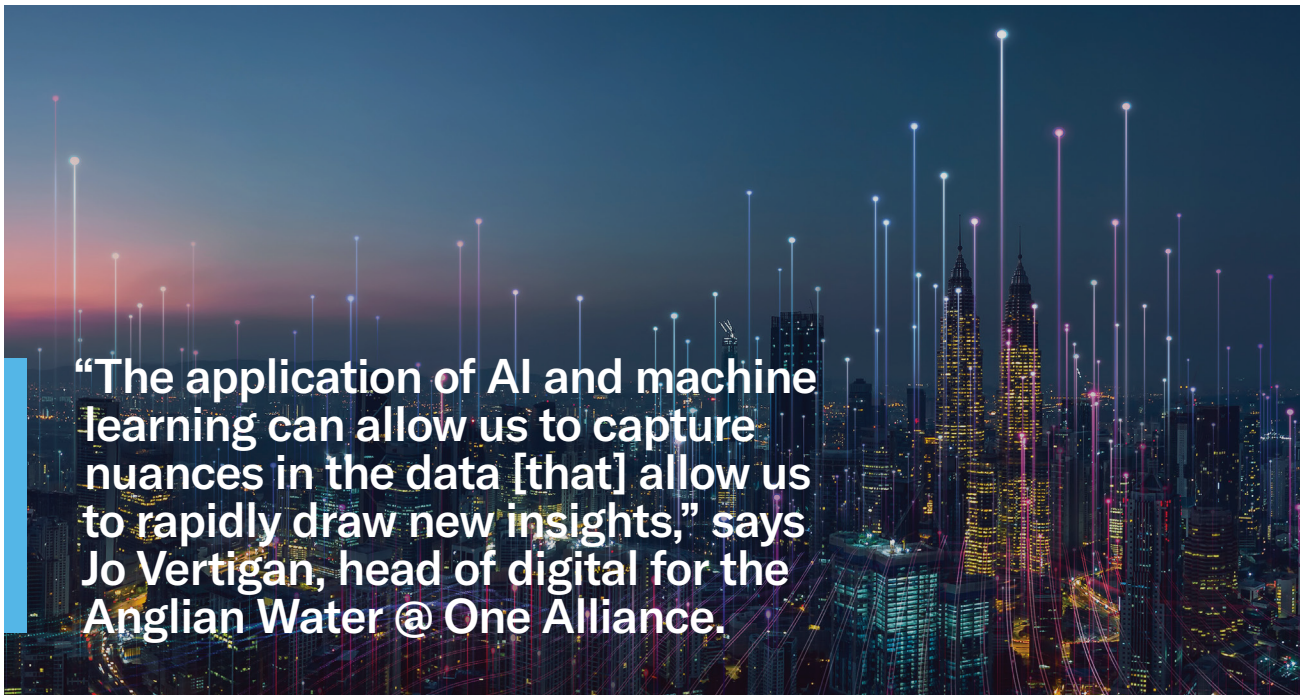
to prepare reports on the current status of work, a key metric, down to just minutes.

"With integrated digital technologies, our project managers can objectively assess project status, productivity, and any risks, and [can] make data-based decisions more quickly to improve safety, performance, and outcomes," says Francesco Tizzani, group manager of digital construction at Leighton Asia, an international construction contractor headquartered in Hong Kong and part of CIMIC Group. "The technologies also reduce manual reporting, enabling our people to focus on analyzing intelligent data to improve project delivery."

Digitization is being used to innovate in all areas at Leighton Asia, including safety, Tizzani says. For example, a safety solution from Nexplore, the wider group's internal software innovation company, has been trialed at a Leighton Asia

McKinsey analysts found front-runners in artificial intelligence (AI) adoption could double their cash flow (economic benefit captured minus associated investment and transition costs) by 2030, with a 122% cumulative change.

"Notes from the AI frontier: Modeling the impact of AI on the world economy," McKinsey & Co., September 2018



construction site. An AI-powered proximity detection camera system monitors exclusion zones (no-go areas around high-risk activities) and raises an alarm if, for example, an operator or worker enters an exclusion zone established to protect them from moving equipment.

But many see these applications as only the beginning. AI is well suited for a wide range of innovative use cases across AEC and D&M design and production processes, from filtering big data to identifying opportunities for sustainability to capturing knowledge from an aging workforce to running simulations. “It can be the codification of human knowledge and intellect,” says Jo Vertigan, head of digital for the Anglian Water @ One Alliance, a partnership of seven companies collaborating on a significant proportion of the British water company’s capital investment program. “The application of AI and machine learning can allow us to capture nuances in the data [that] allow us to rapidly draw new insights.”

Quickly sorting through a multidimensional problem, such as optimizing the parameters for the most sustainable version of a design, frees people to focus their attention in the right places.

“There are so many things where we could make innovations,” says Stanford’s Fischer. “That’s where I see AI being able to give us the insights so we can prioritize what really matters and [what] has the biggest impact.”

As these examples illustrate, AEC and D&M organizations are adopting AI to uncover new insights and optimize choices across a wide range of disparate variables, innovations that would be otherwise very difficult to achieve. These benefits promise to multiply as organizations begin to collect more and better data. Indeed, according to Deloitte’s 2020 “AI Enablement in Smart Manufacturing” survey, 54% of respondents agree, and 39% strongly agree, that AI will be key to growth and innovation in manufacturing. The survey respondents were senior managers at 110 Chinese manufacturing companies.

Digital Twins Bring New Ideas to Life

Digital twins are also increasing their role as a tool of innovation in AEC and D&M. Organizations are tapping digital twins’ ability to create a virtualized version of a product or structure to enable designers and engineers to experiment with designs, materials, and other variables as part of the initial design process. The dynamic nature of digital twins and their ability to represent real-world data and performance on top of a virtual model create a feedback loop between physical and virtual environments. This loop helps users and organizations make better decisions, improve their business practices, and access benefits such as reduced downtime and increased ROI during construction and manufacturing. Digital twins also benefit the ongoing usage of products and buildings.

The global digital twin market is projected to grow at a 58% compound annual growth rate (CAGR) from 2020 to 2026, from $3.1 billion to $48.2 billion, respectively, according to a report from Markets and Markets.[6] The Asia Pacific

INDUSTRY INSIGHT

Tackling Innovation Challenges in Design and Manufacturing

The design and manufacturing (D&M) industry has a long tradition of innovation. But conventional practices, such as assigning the generation of new ideas to a handful of teams, building and testing physical prototypes, and undertaking lengthy market research, are no longer fast or dynamic enough. To work at the pace of today's market requires a new approach to innovation featuring greater speed, more widespread collaboration, and a marked shift in culture.

Pivoting to a more innovative culture can be tough, especially for long-standing manufacturing organizations. One challenge is lack of engineering innovation as an established academic discipline, says Andrew Kusiak, professor of industrial and systems engineering at the University of Iowa. "Since the innovation knowledge is relatively weak, it's difficult for companies to practice it," he says.

Recent attempts to bring in talent in new disciplines, such as data science, have led to culture clashes and distrust, says Jo Geraghty, cofounder of Culture Consultancy, a London-based culture change consulting organization. The D&M industry is also limited in its access to actionable data and its willingness to share the data it does have. Experts interviewed for this report recommend the following steps for D&M organizations to innovate through challenges.

Implement cross-functional teams. Fostering a culture in which every worker is encouraged and empowered to innovate requires deliberate change. Geraghty says innovation hubs can be an effective short-term strategy, but over the longer term, D&M organizations will need diverse, cross-disciplinary teamwork. Her consultancy put workers at a large food manufacturer through an exercise that assigned an innovation task to teams comprising different generations, disciplines, genders, and backgrounds. The success of the exercise led the manufacturer to adopt the practice across larger projects.

"They did come up with innovation that worked," she says. "But the bigger win from it was more about this understanding of, 'Oh, I see the value that your difference brings to the table.'"

Engage universities and startups. That collaborative approach can extend outside the organization to include academic and business partnerships, including working with startups that lack the baggage of entrenched cultures. Partnering can be particularly effective to avoid waging wars for talent across manufacturing organizations, says John Suh, vice president, Hyundai Motor Group, and founding director of New Horizons Studio, a team developing ultimate mobility vehicles (UMVs) based in Fremont, Calif. His group collaborates with third parties to access the most innovative thinking when it comes to UMV design. Collaboration requires working out critical issues, such as intellectual property (IP) and patent ownership, but can benefit all parties in the partnership.

"We are pushing the boundaries in that particular technology area so that organizations will benefit, and they can take that to other economic opportunities," says Suh. "We will fund that, but it is benefiting others beyond us. And we have to be okay with that."

Address data issues. As with IP issues, collaboration in innovation can be used to overcome data issues. Older machinery and equipment may not yet be outfitted to capture useful data. And even when data does get collected, organizations have not always been willing to share it, says the University of Iowa's Kusiak. This issue can be addressed by altering internal policies to catch up to the need to share data to fuel collaborative innovation.

Make room for experimentation. Leadership also needs to make space for workers to innovate: making time, devoting resources, and accepting that failure is inevitable. Workers at every level should feel as safe sharing information about projects that did not go as expected as they do sharing about those that succeeded. Support must extend not only through the innovation process—with all its setbacks, refinements, and early implementations—but also in ensuring adoption. New ideas often need a sustained period of use before they gain acceptance and become fully monetized.

Technology can assist the innovation process by automating manual tasks and uncovering insights that stimulate new ideas.

CONTINUES ON PAGE 8

INDUSTRY INSIGHT

CONTINUED FROM PAGE 7

Culture Consultancy's Geraghty also advocates use of ideation and collaboration tools to capture and share experiences. "A lot of the best ideas for innovation are going to come from your frontline staff because they're the people [who] see what's going on on the ground," she says.

Measure progress. Metrics help keep innovation initiatives on track and identify those with promise. PIX Moving, a Guiyang, China-based multidisciplinary technology developer specializing in robotics and automation, evaluates its own innovations in terms of cost, flexibility, efficiency, the level of "revolution" they represent, and user experience—as well as the impact on its own workforce. The manufacturer's culture emphasizes achieving balance between worker efficiency and fairness. In this setting, "Workers are more willing to use automated equipment, such as robots, to improve efficiency in their daily work, and they are more willing to collect production data to optimize products and production processes," says Angelo Yu, founder and CEO. "A future-oriented culture is required."

region is expected to experience the fastest CAGR, with the manufacturing industry predicted to be the earliest adopter.

According to a global survey conducted by London's Royal Institution of Chartered Surveyors from September to November 2021, 26% of respondents are using digital twins and 18% have started taking the first steps to implementation. The top use cases are facilitating data sharing to deliver performance efficiencies for all stakeholders and gathering real-time site data for decision making and collaboration (each 54%).

"Digital twins will help reduce the developmental cost of some parts of design and demonstration [processes], which can help improve profitability," says Yuya Kajikawa, a professor at the School of Environment and Society at the Tokyo Institute of Technology and at the Institute for Future Initiatives at The University of Tokyo.

Hyundai's New Horizons Studio is putting digital twins of its concept UMV into digitally simulated worlds. The long-term goal is to evaluate the performance of the vehicle in that environment. Because of the complexity of emulating realistic traction of the vehicle on simulated surfaces, New Horizons' shorter-term goal is to show how a UMV might be used in various scenarios in which the physics of the vehicle

The dynamic nature of digital twins and their ability to represent real-world data and performance on top of a virtual model create a feedback loop between physical and virtual environments. This loop helps users and organizations make better decisions, improve their business practices, and access benefits such as reduced downtime and increased ROI during construction and manufacturing.

performance is simplified. That insight gives potential customers a way to understand what a future product could do and provide their feedback, which engineers can then use to iterate new designs without ever having to build a physical prototype.

"If you have a new product type with new capabilities, it's hard to even articulate or even absorb what is the benefit of something that they've never touched before," says New Horizons' Suh. "But if they're interacting with it virtually, they can." Simulating designs and material usage is also helping AEC organizations throughout the building process.

Leighton Asia's Tizzani is excited to see the company leading the way in the use of digital twins. "We are building the asset and its digital twin for our clients. A digital twin begins with a dynamic BIM model of what has to be built. We integrate a project's multiple workflows into the model and input data as the project progresses," he explains. Because Leighton Asia is not locking data into spreadsheets and 2D drawings, the team can use the model and visual reporting to collaborate on change management. Then, they can use simulation and machine learning to help decision making, improve efficiency, and reduce rework. "When construction is completed, the digital twin is invaluable for operations and maintenance across the asset's life," Tizzani adds.

While current progress is encouraging, the potential for digital twins to transform much of the process of designing and producing goods and structures in AEC and D&M still lies ahead. By increasing the volume and variety of their data collection activities, organizations can lay a foundation to reap insights and drive experimentation in the future.

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Innovation through Next-Gen Design Approaches

The need to elevate organizations' capacity to innovate is also driving increased use of generative design and design for manufacture and assembly. Generative design is a design exploration process that takes into account design goals, parameters, and constraints to quickly generate and test design alternatives. DFMA enables engineers to incorporate construction into early design phases, when changes are less costly. It also enables designers/architects, engineers, fabricators, contractors, and subcontractors to work hand in hand in the design process and collaborate on goals, such as reducing time and total project costs. Architects, for instance, can know how each part will be fabricated and assembled so they can optimize their designs consequently. And manufacturers and fabricators can share their constraints in advance so that architects or designers can take them into account. Efficiency in the design process provides huge benefits in cost and efficiency downstream as projects progress.

Bryden Wood uses generative design in several ways to infuse innovation into its processes, including helping "serial" builders that need to erect variations of the same asset on multiple sites. Instead of designing each location as a one-off using conventional approaches, generative design can quickly produce 100,000-plus proposed variations, which can be "down selected" according to a client's value drivers to arrive at the ideal design for each individual site. That success enabled Bryden Wood to take the generative design concept to the next level by asking what *else* the organization could do by having an optimized design in hand. The company used automated design to develop a rapid-assembly, highly accurate set of parts for the superstructure of The Forge, a net-zero carbon commercial office project in South London.

"We then [asked] the mechanical and electrical contractor, 'If you knew that the superstructure was super precise, all your fixing points are already in the slab, and they're also very accurate, what would you do with that?'" says Bryden Wood's Johnston. In a conventional project, the mechanical and electrical contractor would install electrical components manually on-site as a series of individual trades due to the inevitable variation in, say, the placement of a column. But because the superstructure was built to the design's exact specifications, the electrical contractor was instead able to create multiservice cassettes containing mechanical and electrical components in a factory, then wheel those into position and quickly raise each one into place. Essentially, the contractor could design for manufacturing and assembly. "The install time collapsed from hours to minutes," says Johnston. The same concept, applied to pieces of the façade, cut the time required to install each panel from an hour to seven and a half minutes.

The ability to consider manufacturing and automated assembly processes in the design stage will particularly bring value as more production processes are handled by robots, notes New Horizons' Suh. "We'll link our digital models of the components designed for automated assembly; then

Efficiency in the design process provides huge benefits in cost and efficiency downstream as projects progress.

that file will go straight to the robot that makes and joins the components," he explains. "Then on-site, people will use simple automation to support final assembly of the subassemblies quickly and accurately."

By adopting generative design and DFMA, AEC and D&M organizations are increasing their ability to generate, test, and collaborate on ideas early in the design process, enabling them to develop innovative approaches to how they work while also minimizing cost and increasing efficiency. As the use of generative design and DFMA continues to expand, they promise to bring far greater collaboration and cohesion to end-to-end processes in both AEC and D&M.

Stimulating New Approaches to Sustainability

There is perhaps no greater need for innovation than in increasing the sustainability of design, production, and construction processes. As the aforementioned pressure from governments and clients to create more sustainable products, processes, and structures continues to rise, AEC and D&M organizations will increasingly leverage AI and modeling tools and techniques to arrive at new designs that balance purpose, sustainable design and materials, and economic factors.

"There is generally a trade-off between environmental sustainability and economic efficiency," says The University of Tokyo's Kajikawa. AI and modeling can be tuned to help humans make those decisions in a complex trade-off, he says.

A Capgemini Research Institute survey of 480 global manufacturing executives conducted in February and March 2021 found that organizations are already seeing sustainability benefits from scaled digital technologies including automation, AI/machine learning, and data analytics. **FIGURE 2** For example, respondents report an average 15% reduction in waste over the past two years and another 20% expected over the next five. According to the report, "Innovation, driven by technology and data, can help manufacturers address both sustainability and economic concerns simultaneously."

"When you look at building structures and you're trying to remove carbon from your building, you're trying to reduce energy in use, but you also need to look at the embodied carbon within the building itself, the materials," says Jacqui Glass, vice dean of research and a professor in construction management at University College London.

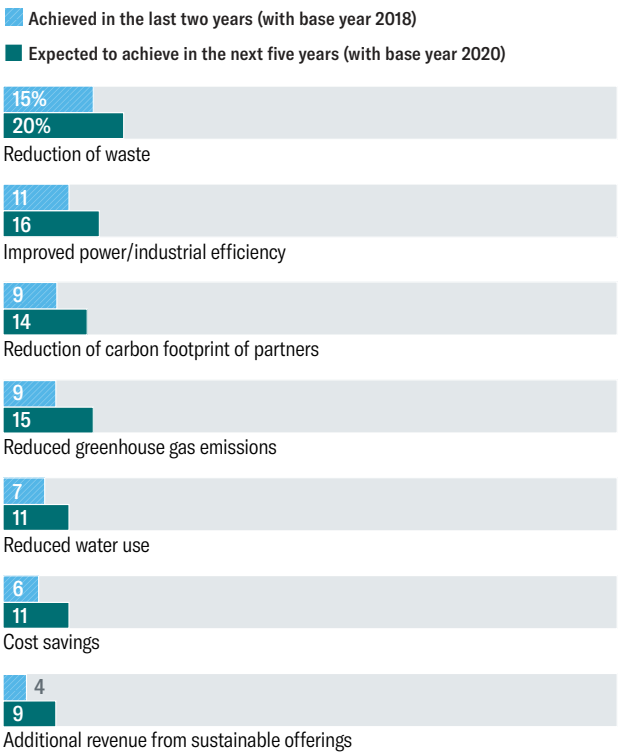
One example of innovation in sustainability, she notes, is the Automating Concrete Construction project at the U.K.'s University of Bath, which seeks to dramatically improve sustainability and productivity in construction by defining a holistic approach to the manufacture, assembly, reuse, and deconstruction of concrete buildings. Machine learning, a subset of AI that allows a machine to automatically learn from past data without specifically being programmed for

FIGURE 2

Digital Investments Deliver Sustainability Benefits

Manufacturers report payoffs from scaled use of digital technologies including automation and artificial intelligence/machine learning

What are the average sustainability benefits from scaled digital technologies?



Source: Capgemini Research Institute, 2021

that purpose, is being used to design smart slabs that are then created using concrete frames, cutting material use by up to 50% by ensuring concrete is placed only where it is needed to provide sufficient stability and strength. Then 3D printing and robotic production improve the efficiency of the production process. "That's a really nice demonstration of how you're bringing together the technologies to drive innovation in how construction processes can be made more sustainable," Glass says.

As the need for greater sustainability in manufacturing and construction processes and materials has gained urgency, AEC and D&M organizations are turning to innovation to break through the limitations of traditional practices. Approaches incorporating AI, digital twins, generative design, and DFMA promise to enable new ways of working that remove waste, speed processes, reduce costs, and create far more cohesive, integrated ways of working.

Discovering new ways to remove time, materials, and other costs from the design and production of goods and buildings requires overcoming some considerable obstacles. AEC and D&M companies must tackle the organizational, cultural, and technological challenges unique to their industries to successfully lay the groundwork for more innovative practices.

Addressing Complex Challenges with Innovation

AEC and D&M industries have always faced challenges, of course. But today's competitive and customer pressures, sustainability and workforce challenges, and rising mandates are being felt more intensely than before. Many see innovation as the key to unlocking the new materials, processes, and creative energy required to meet this moment.

Increased focus on innovation is driving AEC and D&M organizations to explore tech-enabled ways of working. AI and approaches including digital twins, generative design, and DFMA are automating rote processes and helping people discover, test, and implement better ways to achieve organizational goals. Early adopters of these technologies, including Bryden Wood and PIX Moving, are seeing marked reductions in capital costs and design and production time frames and discovering more sustainable materials and methods.

"In this day and age, there is no option other than to innovate in order to grow," says Jo Geraghty, cofounder of Culture Consultancy.

To truly reap the benefits of new tech-enabled approaches to innovation, organizations are also changing how they work. In AEC, successful strategies include changing how contracts are structured, improving data collection and analytics, and creating a more formal structure for infusing innovation into day-to-day work. In D&M, fostering more diverse, cross-functional internal teams, collaborating with universities and startups, and making room in the culture for innovation are helping organizations successfully nurture and monetize new ideas. Experts are confident that those able to clear the hurdles to adoption are poised to benefit from embracing innovation across their ecosystems.

"In this day and age, there is no option other than to innovate in order to grow," notes Culture Consultancy's Geraghty.

Endnotes

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