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

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, construction and manufacturing industries have low margins, face an ageing workforce, and strain to adapt to new patterns of manufacturing, such as industrialised 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 insights.

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 behavioural 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.

Mike Haley
Vice President
Autodesk Research

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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 organisations 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 organisations to work better, faster and more sustainably and efficiently while reducing costs. A 2021 survey of 1,843 global cross-industry organisations 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, California. "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 beyond niche-use cases to impact the larger

HIGHLIGHTS

Organisations in the manufacturing and construction ecosystems sometimes **struggle to identify and monetise innovative ideas**.

Organisations 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**.

organisation 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 organisations in the manufacturing and construction ecosystems sometimes struggle to identify and monetise innovative ideas. Common obstacles to fostering and operationalising innovation include cultural resistance, entrenched business practices, and uncertainty about how to instil innovation-enabling processes.

Organisations seeking to monetise 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 an understanding of 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 towards innovation-nurturing business practices and cultures. Successful moves include establishing diverse, cross-functional teams and formalising 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 organisations that moved more aggressively than their competitors to adopt processes, technologies and mindsets that enable innovation and are enjoying significant benefits as a result.
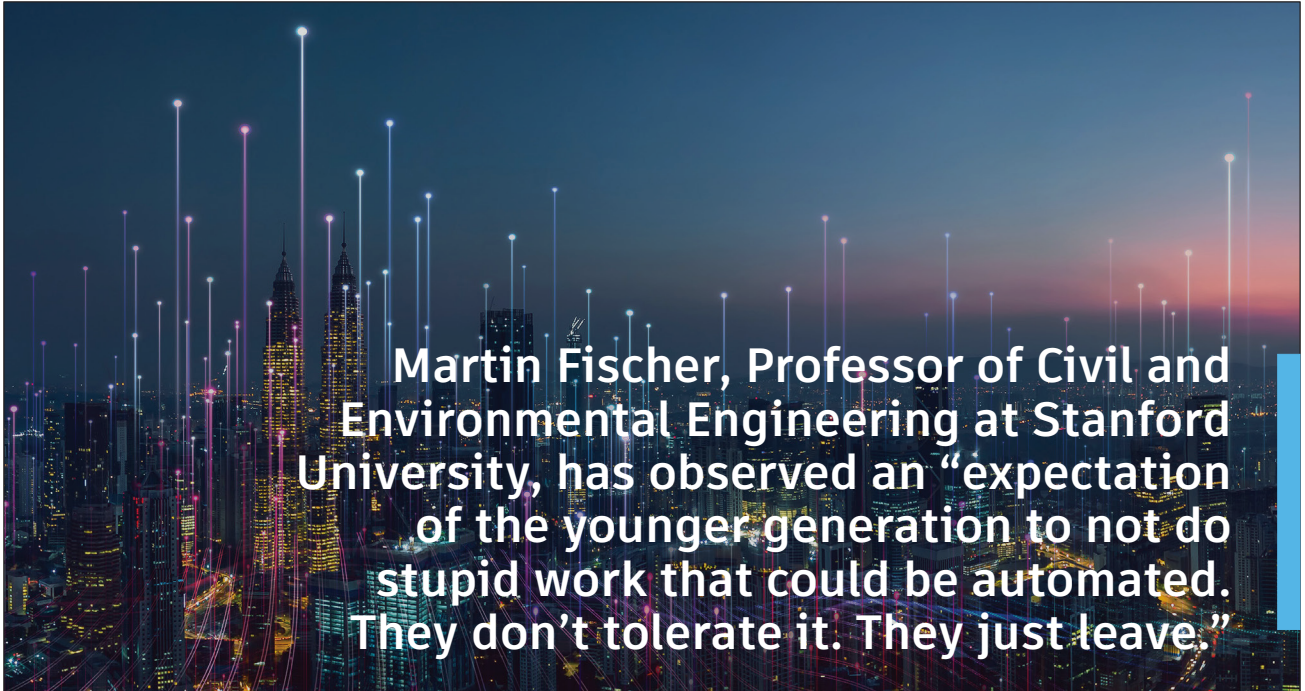
The ability to significantly reduce the resources needed to design, engineer and build something, whether it's a scooter or a skyscraper, offers a clear competitive advantage over traditional methods. As Forrester's findings confirm, organisations investing in the innovation required to approach old problems in new ways enjoy greater growth. But signs suggest that 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 organisations' 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 unfavourable working conditions.

Attempts to attract new talent to industrial organisations 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 organisation. Organisations need ways for new recruits 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

Martin Fischer, Professor of Civil and Environmental Engineering at Stanford University, 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."

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 dialling up the heat. Governments from the United Kingdom to Brazil to Mexico are mandating or heavily pushing the use of building information modelling (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, affecting both AEC and D&M organisations. For the cement and construction value chain, for example, this goal will require tripling the current pace of decarbonisation. 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 i

ndustries, organisations 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 mobile data networks and the cloud. Beyond simply digitising existing analogue processes using this data, organisations are increasingly digitalising them – rearranging business processes by sharing and collaborating on digital information in new ways, with information at the centre of this new operating model. AEC and D&M organisations 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.

Non-adopters [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 that 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** Non-adopters "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 organisations 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 customised 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 customisation needs, and a mould-free approach, all of which reduce costs significantly for the organisation.

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 set-up, 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 decentralised, and no more moulds 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 analysing image data captured by cameras mounted on cranes – and, increasingly, drones – construction companies are substantially reducing the many hours and

FIGURE 1

Advantages accrue to early adopters

By 2030, front-runners in adopting artificial intelligence could double their cash flow
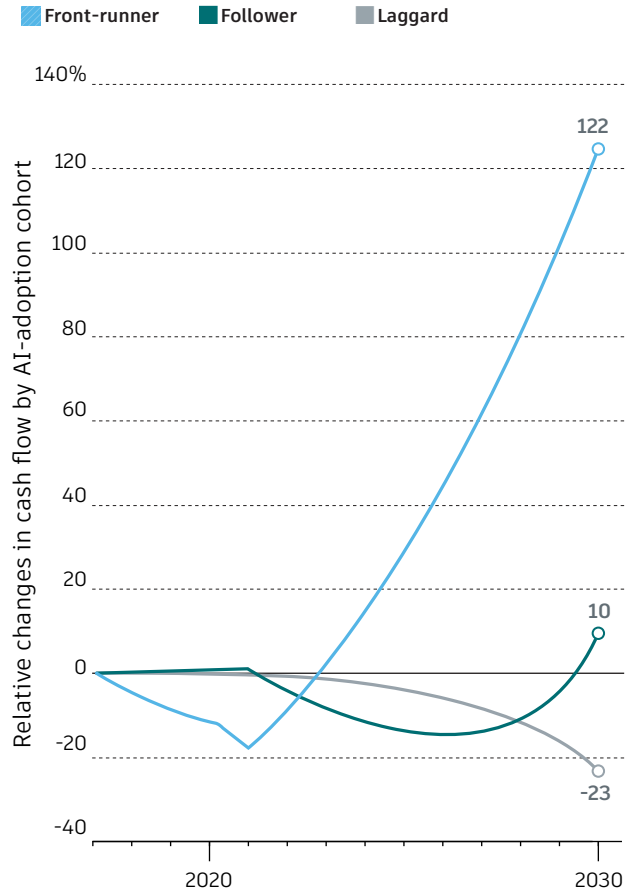
Source: McKinsey & Co., September 2018

people it takes to prepare reports on the current status of work, a key metric, down to just minutes.
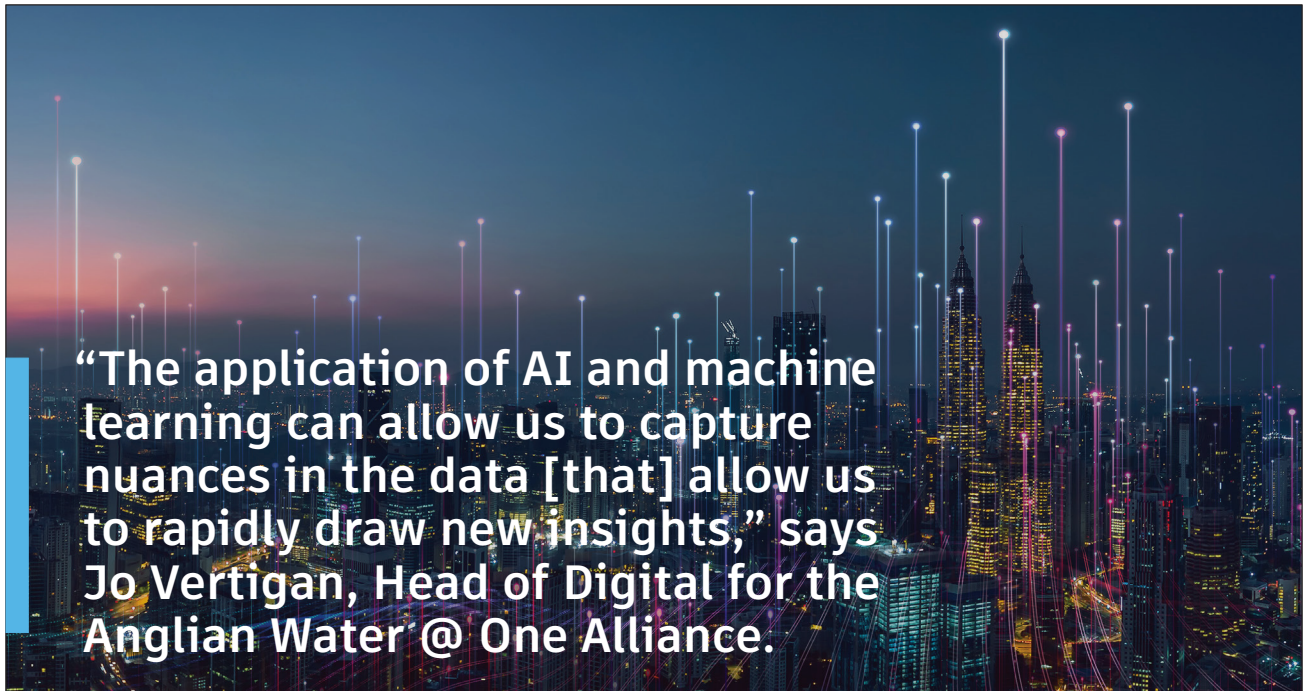
"With integrated digital technologies, our project managers can objectively assess project status, productivity and any risks, and [can] make data-based decisions more quickly to improve safety, performance and outcomes," says Francesco Tizzani, Group Manager of Digital Construction at Leighton Asia, 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 analysing intelligent data to improve project delivery."

Digitisation 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 trialled at a Leighton Asia construction site. An AI-powered proximity

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: Modelling the impact of AI on the world economy," McKinsey & Co., September 2018

"The application of AI and machine learning can allow us to capture nuances in the data [that] allow us to rapidly draw new insights," says Jo Vertigan, Head of Digital for the Anglian Water @ One Alliance.

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 ageing 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 programme. "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 optimising 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 prioritise what really matters and [what] has the biggest impact."

As these examples illustrate, AEC and D&M organisations are adopting AI to uncover new insights and optimise choices across a wide range of disparate variables – innovations that would be otherwise very difficult to achieve. These benefits promise to multiply as organisations

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. Organisations are tapping digital twins' ability to create a virtualised 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 organisations 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 region is expected to experience the fastest CAGR, with the manufacturing industry predicted to be the earliest adopter.

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 organisations. 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 practise 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 organisation. 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 organisations 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 organisations 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 start-ups. That collaborative approach can extend outside the organisation to include academic and business partnerships, including working with start-ups that lack the baggage of entrenched cultures. Partnering can be particularly effective to avoid waging wars for talent across manufacturing organisations, 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, California. 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 organisations 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, organisations 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 with 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 to ensuring adoption. New ideas often need a sustained period of use before they gain acceptance and become fully monetised.

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

INDUSTRY INSIGHT

Culture Consultancy's Geraghty also advocates the 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 specialising 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 emphasises achieving a 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 optimise products and production processes," says Angelo Yu, founder and CEO. "A future-oriented culture is required."

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 performance is simplified. That insight gives potential customers a way to understand what a future product could do and provide their feedback,

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 organisations make better decisions, improve their business practices, and access benefits such as reduced downtime and increased ROI during construction and manufacturing.

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 organisations 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, organisations 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 organisations' 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 optimise 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 or more 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 organisation could do by having an optimised 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 that file will go straight to the robot that makes and joins the components," he explains. "Then on-

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

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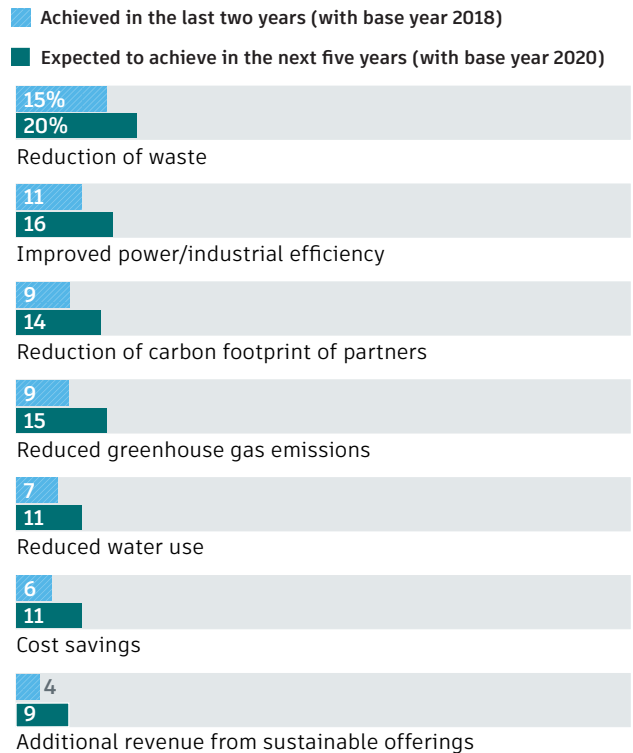
One example of innovation in sustainability, she notes, is the Automating Concrete Construction project at the UK's University of Bath, which seeks to dramatically improve sustainability and productivity in construction by defining a holistic approach to the manufacture, assembly, reuse and deconstruction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

FIGURE 2

Digital investments deliver sustainability benefits

Manufacturers report pay-offs from scaled use of digital technologies, including automation and artificial intelligence/machine learning

What are the average sustainability benefits from scaled digital technologies?

■ Achieved in the last two years (with base year 2018)

■ Expected to achieve in the next five years (with base year 2020)

15%	Reduction of waste
20%	
11	Improved power/industrial efficiency
16	
9	Reduction of carbon footprint of partners
14	
9	Reduced greenhouse gas emissions
15	
7	Reduced water use
11	
6	Cost savings
11	
4	Additional revenue from sustainable offerings
9	

Source: Capgemini Research Institute, 2021

that 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 organisations 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 up 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 organisational, 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 organisations to explore tech-enabled ways of working. AI and approaches including digital twins, generative design and DFMA are automating rote processes and helping

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

people discover, test and implement better ways to achieve organisational 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.

To truly reap the benefits of new tech-enabled approaches to innovation, organisations 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 start-ups, and making room in the culture for innovation are helping organisations to successfully nurture and monetise 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.

End notes

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