GLOBAL INFRASTRUCTURE INITIATIVE
By McKinsey & Company

Voices on Infrastructure

Harnessing the promise of digital

March 2018

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Introduction: Harnessing the promise of digital

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Welcome to the March 2018 issue of *Voices on Infrastructure*, a collection of insights from McKinsey and industry experts on **harnessing the promise of digital.**

After a long legacy of reluctance to embrace new technology, capital project and infrastructure leaders are quickly realizing that digital is no longer an option. And digital solutions are proliferating to meet the need, with $10 billion in investment flowing into construction-technology firms between 2011 and early 2017. In shaping this compendium of insights, three themes rose to the fore:

Defining the business value: Leaders frequently lack clarity around the value of individual solutions, making them difficult to adopt in a holistic and coherent fashion. This shortfall is a major barrier to successful digitization. Visibility into technology's impact on the bottom line is crucial to design the right combination of levers to deliver that value. At the same time, it is vital for enterprises to move away from a world of proliferated systems, with scattered spreadsheets and documents, and into a coherent, state-of-the-art, project-centric enterprise backbone. This shift will entail longer-term investments into R&D and IT—areas that are typically underfunded in this industry.

Organizing the ecosystem: With myriad tools and solutions emerging and gaining traction, how can leaders best understand and prioritize their investments? From advanced analytics to artificial intelligence to virtual reality, we delve into how specific technologies are improving the way we build, operate, and communicate about built assets. The best-in-class will distinguish themselves through new approaches to automated design, cross-project optimization, and an integrated lifecycle approach to projects that is rarely seen today.

Mobilizing for success: Tools alone are not enough to realize the digital opportunity, and organizations must fundamentally alter the way they work to achieve true value. Progress will be at least as much about attracting new digital talent as it will be about upskilling the existing workforce. With these insights, we aim to outline actionable steps that leaders can take to kickstart, scale, and sustain their digitization efforts.

We are past the precipice of change, and leaders must act now to develop their digital strategies. As proven by other industries that are more digitally advanced, those who wait for proven success stories will be too late to catch up to the competition. We hope these perspectives bring new understanding about how technology is shaping our evolving sector and support readers in pursuing and developing successful digital transformations.

News from the Global Infrastructure Initiative

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Director of the Global Infrastructure Initiative, McKinsey & Company

Welcome to the March 2018 edition of *Voices*, a compilation of insights on harnessing the promise of digital technologies in infrastructure and capital projects. As this historically underdigitized industry faces a new wave of technological change, we hope these collective perspectives will alert readers to the potential and inspire you to chart a course toward successful transformation.

The year has been off to a busy start for the GII community, as we strive to stimulate change in the industry through our activities. Last month, we hosted an innovation site visit to the headquarters and test site of Virgin Hyperloop One, the only company to have built a full-size and full-system hyperloop—a proposed mode of electrified, autonomous, high-speed transportation. It was an intriguing foray into the potential future of transportation, understanding how this new technology might impact existing business models and value chains. You can read a summary of key themes here.

We also convened senior leaders for two regional roundtables in March—a gathering on airport customer experience in Orlando, Florida and a conversation on construction's digital revolution in Madrid. In both of these spheres, new technology and rising customer expectations are pressuring leaders to dramatically rethink their ecosystems and rapidly improve performance. We will continue these conversations in the months and years to come, including at our 5th Global Infrastructure Initiative Summit in London this October.

In the second quarter of 2018, GII will host May roundtables in Dubai on digital construction and in Sydney on technology in transport. Please email us to learn more about either of these events. We are also excited to organize a site visit to Moscow, where leaders will explore some of the city's recent and upcoming major projects in urban development.

We hope you enjoy this edition of *Voices* and that it sparks new ideas for you on the digital future of capital projects and infrastructure. Our June issue will center on major projects as we bring forth perspectives on how to improve outcomes on the world's largest, most complex projects. We look forward to sharing it with you, and we welcome your thoughts on *Voices* at any time.

Photo credit: iStock

Going digital to advance infrastructure delivery: The *open information* project

Owners and contractors can share "integrated project delivery" benefits on any project—including digital workflows and increased visibility—through a connected data environment.

Greg Bentley

CEO, Bentley Systems

To improve upon the unfortunate backdrop of infrastructure capital projects typically being delivered late and over budget, infrastructure owners can reasonably expect the efficiencies and rigors of "going digital" to both make project performance more predictable at the outset and provide greater visibility during their course. To date, though, the benefits of building information modeling (BIM) have tended to be limited in scope to the work within individual disciplines or phases. New advances in computing and software now make project-scale improvements possible—from conception through construction and commissioning. Realizing this potential, however, depends not just upon this new level of information technology integration but also, as importantly, upon a change in mind-set across the project. Not only the owner but also each participant can benefit to the extent that their own digital work is appropriately accessible to and securely shared with the others, to purposefully enable automated workflows and digital visibility spanning the overall project.

Consider a project delivery firm whose business model heretofore has been within separate design, bid, or build phases—but which becomes party to a contract for integrated project delivery (IPD), assuming or sharing responsibility throughout all phases. Suddenly this firm's imperative would be to take full advantage of potential "digital workflows" in which their software tools would start from the searchable (not paper) results of software tools used in previous project phases, and then in turn provide outputs to be applied by software tools in subsequent phases, all to maximize synergies and minimize errors. The risk and reward outcome of the IPD contract would depend upon the extent and quality of this information integration and its robust automation.

Now, imagine the upside if the same project-level digital workflow strategies were to be availed across all participants on any project, regardless of the contracting model. In this scenario, a connected data environment (CDE), provisioned by or for the owner as a cloud service, captures and intelligently shares all digital work packages, enabling participants to automate their collaboration protocols as if they were one project enterprise. In addition to benefiting from unprecedented visibility into project performance, the owner's supply-chain choices need not be limited to the few (if any) organizations capable of shouldering IPD risks. The result is that the IPD advantages are achieved and even exceeded (synthetically, rather than contractually). This scenario—an *open information* project—is now possible.

The *open information* project premise

Despite increasing momentum within infrastructure project delivery to embrace digital technology, to date most benefits have been constrained to individual BIM deliverables, rather than to their integration for improved overall project performance. Each discipline and trade creates its own idiosyncratic 3-D digital models, usually in a format that at best would be inscrutable to other participants—and thus highly vulnerable to mutual inconsistencies. Project coordination must then rely upon, and be limited to, periodic design reviews entailing the time-consuming and manually orchestrated export, import, and translation of incompatible native files, jeopardizing intellectual property (IP) in their exchange. Furthermore, the after-the-fact corrections necessary to resolve interferences between disciplines or trades may already have been outdated by constant project changes, unless progress is stopped for the duration of each design review.

Significantly, however, advances in cloud computing and software platforms now enable an *open information* project's CDE to facilitate continuous digital workflows across the project's supply chain and throughout its lifecycle phases. Consultants and contractors can apply their preferred digital tool sets, while the CDE collates the contents of these disparate but known file formats into self-describing "digital components" for semantic alignment across disciplines and trades. Accordingly, 3-D visualization of the project data can be supplemented with visibility into its meaning, including for instance the "4-D" and "5-D" attributes supporting digital workflows for off-site fabrication.

Key enabling factors of an *open information* project, of course, are its security provisions. On the one hand, the CDE leverages industrial-strength cloud services that can be more robust and secure than an end-user organization's comparatively vulnerable internal environment. On the other hand, while it is vital that each participant undertakes to deliver and to conscientiously update their digital work packages to be accessed as usefully needed across the project, secure workflow protocols assure that the participant's transitory work in progress is only "locally" accessible.

A representative *open information* project charter

Achieving the potential of going digital at project scale requires both CDE technology and the commitment by the project supply chain to endorse digital workflows. Owners must convince and catalyze all participants to empower, enrich, and take full advantage of their *open information* project.

Based on experience, I believe that virtually every infrastructure project delivery participant, given the opportunity, would be willing and able to contribute toward—and gain from—the digital workflows enabled within an *open information* project. Nonetheless, to overcome pre-digital mind-sets, explicit owner leadership is essential in engendering the requisite behavior changes. To set expectations and avert misconceptions among contractors, the following collaboration precepts, as an example, should be accepted by all, as qualifying conditions for working on the project:

- All design and construction engineering work, and work packages at every contractual level, are to be maintained in the project CDE. Work in progress need not be sharable, but activity journals (including what shared information has been queried or updated) are to be generally accessible.

- Each participant is to regularly update a progressively more complete version of their own scope that is to be accessible to (but cannot be changed by) other participants, for queries and continuous integrated reviews of design and construction status.

- Digital models are to be intrinsically geo-coordinated for 3-D positioning within the project's "digital context"—that is, the digital visualization of the work site in the CDE.

- Each participant is to proactively subscribe to the automated notifications of changes by other participants, where and at such levels of detail as can appropriately inform their own work.

- So long as each participating organization complies with requirements applicable to their project phase (for example, BIM execution plan), each can independently choose between professionally accepted software tools.

- Digital access does not confer to any participant, nor the project owner, the right to any IP nor the reuse, beyond the project, of any work product of any other participant.

- No CDE access is granted or enabled beyond authorized project participants who have accepted this *open information* project charter.

How project delivery supply chain participants benefit

The mere availability of project-wide information is made much more valuable by the CDE's capability to present it in the means most fit for the purposes of project delivery participants, supplementing immersive visibility with digital alignment and change synchronization.

Indeed, the work of all infrastructure project participants shares a dependency upon the evolving conditions at the physical work site. By way of the CDE, this digital context can be most usefully represented as an engineering-ready, 3-D "reality mesh" processed from photographs, scanned imagery, or both, and then updated continuously through regular drone surveys. This real-time digital context enables immersive visualization, including through ever-advancing virtual reality and augmented reality devices, to intuitively locate and query any information within the CDE by spatial reference. In so doing, the digital context positionally aligns the respective models of each discipline and trade. Accordingly, throughout the project each participant's work planning and packaging can fully consider the status, sequence, and safety factors of other participants' work.

The advantages of such proactive information sharing would be ephemeral without also making it practical to react in a timely manner to inevitable, unanticipated changes as the project progresses. For this purpose, the CDE journalizes changes in work packages and can provide automated notifications to appropriately subscribing participants, for their visual review and (to the extent they deem the indicated changes to be significant for their own work) potential synchronization.

In effect, for an *open information* project, design and construction status reviews thus become continuous and comprehensive. Each discipline and trade can increase their ability to avoid errors and interferences, and gain visibility to improve schedule and safety, with benefits compounded for the performance of the project as a whole.

How project owners benefit

Among an *open information* project's myriad benefits to owners, it naturally pre-provisions the completions and commissioning phases, accelerating investment returns from asset performance. Moreover, the digital context and digital component data, cumulatively populating the CDE from design through construction, can then help serve as the asset's "digital DNA" for operations and maintenance. And of course, project owners are the

ultimate beneficiaries of the capacity for continuous and comprehensive design reviews during project delivery—improving the owner's project performance visibility (beyond what is afforded in an actual IPD project) into emerging problems in time for intervention to avert schedule or cost overruns.

By comparison, owners' primary project insight to date has been limited to external experts' post-mortem benchmarking, based on belated survey questions. And while it is challenging for owners to sustain in-house engineering experience, their organizations' capability to apply business analytics to improve enterprise performance is growing apace. Unfortunately, despite the magnitude of infrastructure capital projects risk, the associated engineering information has heretofore been inaccessible—as "dark data", beyond analytics' comprehension and in any event not reliably up to date.

In an *open information* project, the illuminating digital alignment and change synchronization functions within the CDE will now empower owners to fruitfully deploy analytics for visibility into project performance. Importantly, analytics will not purport to qualify the owner to second-guess the contractors' substantive engineering decisions. But it will be possible for owners' analytics, through automated monitoring of the CDE, to assay and dashboard the quality and consistency of project information. For example, analytics could continuously compare scheduled work package requirements against the on-the-ground reality of craft resource availability.

Increasingly, project owners will then also benefit from applying analytics' machine learning across a portfolio of *open information* projects, for instance to establish correlations between completed projects' realized performance and their respective information "footprints." The voluminous CDE activity journals of current projects would be surveilled for patterns (perceptible only with such analytics) to indicate the extent to which a project is on or off track, based on actual experience.

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In an *open information* project, the BIM advancements that individual infrastructure project delivery participants have adopted to improve their own scope are extended, through a CDE, to digital workflows across the project supply chain to advance overall project performance. The supporting technologies are now available, requiring only the initiative of project owners to lead their supply chain to the benefits, for each and to all, of embracing an *open information* project charter. Accordingly, going digital—provided also in mind-set—can finally make infrastructure projects more bankable!

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.

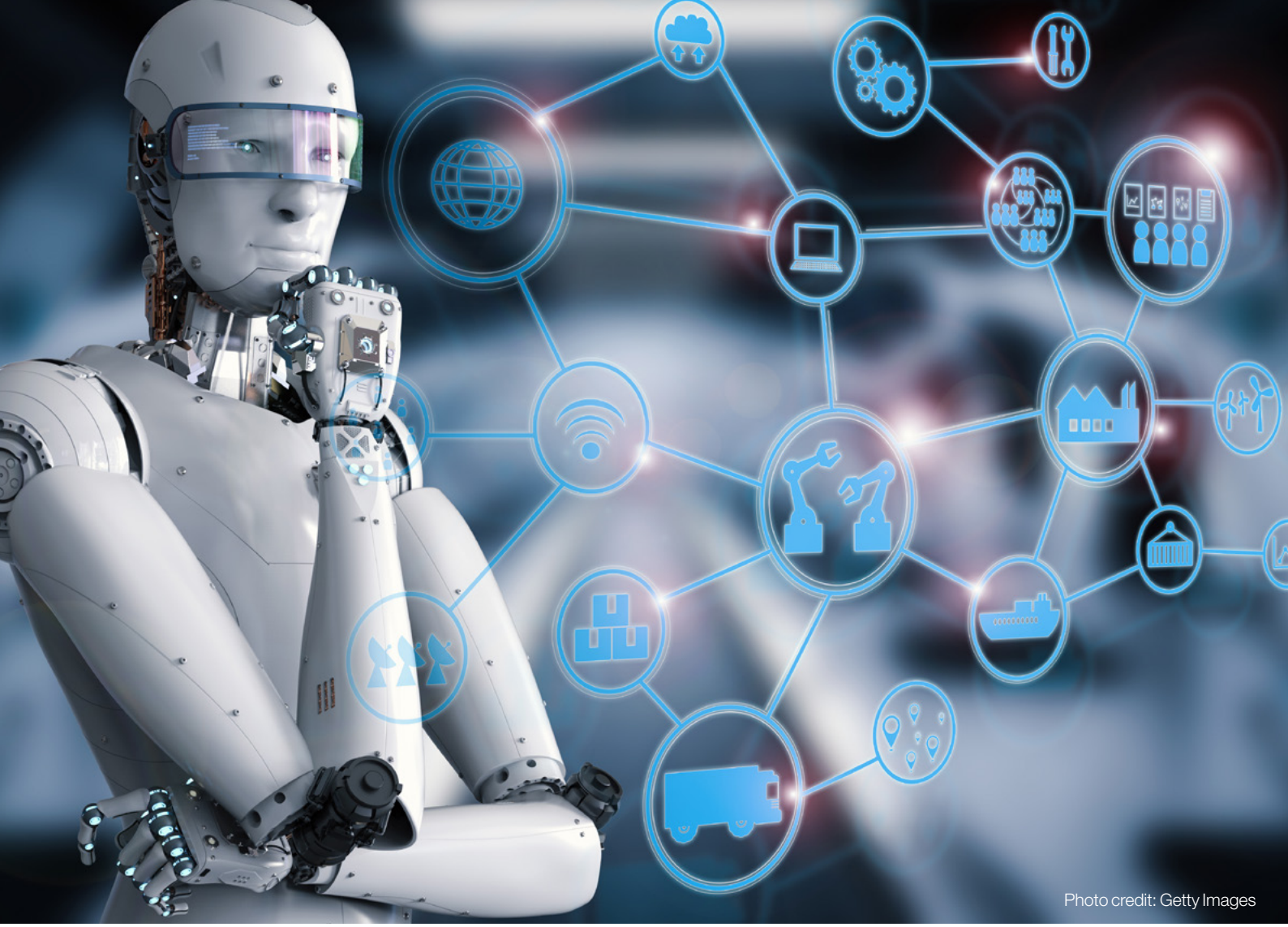

Photo credit: Getty Images

Artificial intelligence: Construction technology's next frontier

Engineering and construction is behind the curve in implementing artificial intelligence solutions. Based on extensive research, we survey applications and algorithms to help bridge the technology gap.

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The engineering and construction (E&C) sector is worth more than $10 trillion a year. And while its customers are increasingly sophisticated, it remains severely underdigitized. To lay out the landscape of technology, we conducted a comprehensive study of current and potential use cases in every stage of E&C, from design to preconstruction to construction to operations and asset management.[1] Our research revealed a growing focus on technological solutions that incorporate artificial intelligence (AI)-powered algorithms. These emerging technologies focus on helping players overcome some of the E&C industry's greatest challenges, including cost and schedule overruns and safety concerns.

In the immediate future, we expect AI's proliferation in the E&C sector to be modest. Indeed, despite proven high return on investment (ROI) and widespread management interest in AI solutions, few E&C firms or owners currently have the capabilities—including the personnel, processes, and tools—to implement them.[2]

However, a shift is coming. Stakeholders across the project lifecycle—including contractors, operators, owners, and service providers—can no longer afford to conceive of AI as technology that's pertinent only to other industries. Indeed, adjacent industries, such as transportation and manufacturing, are already in the process of breaking down the barriers between one another and operating more as ecosystems (for example, solutions, tools, and algorithms that were industry-specific are more likely to become effective having impact across industries)—increasing the threat of competition from market entrants that have not traditionally been capital project players.[3]

These lowered market barriers are compounded by the increasing ability of AI methods to work across industries. These advances will be seen in the mid- to long-term, but to play a role in future ecosystems—and to compete with incoming market entrants—E&C will need to catch up in its adoption of AI applications and techniques. We predict this effort will lead to the allocation of more resources to build the necessary capabilities, and to AI playing a more significant role in construction in the coming years.

So where should E&C leaders begin? Building on last year's report, we offer predictions for where and how AI can infiltrate construction across three categories:

- Examining where AI solutions are beginning to emerge in construction today.
- Exploring AI-powered applications and use cases that have already made an impact in other sectors and that can be applied in the construction industry.
- Assessing additional machine learning algorithms and their potential E&C applications.

1 For more information, see Jose Luis Blanco, Andrew Mullin, Kaustubh Pandya, and Mukund Sridhar, "The new age of engineering and construction technology," July 2017, McKinsey.com.

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

3 For an example of the impact platforms and ecosystems will have on industries, see Tanguy Catlin, Johannes-Tobias Lorenz, Jahnavi Nandan, Shirish Sharma, and Andreas Waschto, "Insurance beyond digital: The rise of ecosystems and platforms," January 2018, McKinsey.com.

The current state of AI in engineering and construction

AI use cases in construction are still relatively nascent, though a narrow set of start-ups are gaining market traction and attention for their AI-focused approaches. There are a few early-stage examples construction firms can evaluate:

- Project schedule optimizers can consider millions of alternatives for project delivery and continuously enhance overall project planning.

- Image recognition and classification can assess video data collected on work sites to identify unsafe worker behavior and aggregate this data to inform future training and education priorities.

- Enhanced analytics platforms can collect and analyze data from sensors to understand signals and patterns to deploy real-time solutions, cut costs, prioritize preventative maintenance, and prevent unplanned downtime.

Still, adoption of AI solutions is quite low in E&C, particularly compared with other industries (Exhibit 1). McKinsey research compared building materials and construction to 12 other industries; ten of those industries are further along in current AI adoption, and all 12 are projected to increase spending on AI at a faster pace over the next three years.[4]

Of course, any AI algorithm is based on learning from the past. This means that AI needs a certain critical mass of data to deliver on its promise so scale will matter; as such, firms will need a significant amount of data (in this case projects) to train an AI algorithm. Therefore, the largest companies are likely to benefit more, particularly in the short term.

It is possible that an external third party enters and leverages E&C data to train its models—a scenario that would likely result in improvement across the industry as a whole but limited competitive advantage for individual firms—but this seems unlikely given the enormous restrictions on data sharing and data ownership.

Five AI-powered applications from other industries transferrable to construction

AI encompasses a large universe of possibilities and use cases, including machine learning, natural language processing, and robotics. Our research has homed in on five AI applications used in other industries that have direct application in the construction sector:

Transportation route optimization algorithms for project planning optimization.
Currently available technology already offers transportation companies the ability to optimize routes and improve traffic navigation. In the future an AI technique called reinforcement learning, which allows algorithms to learn based on trial and error, could provide even more

4 Michael Chui, James Manyika, and Mehdi Miremadi, "What AI can and can't do (yet) for your business," McKinsey Quarterly, January 2018, McKinsey.com.

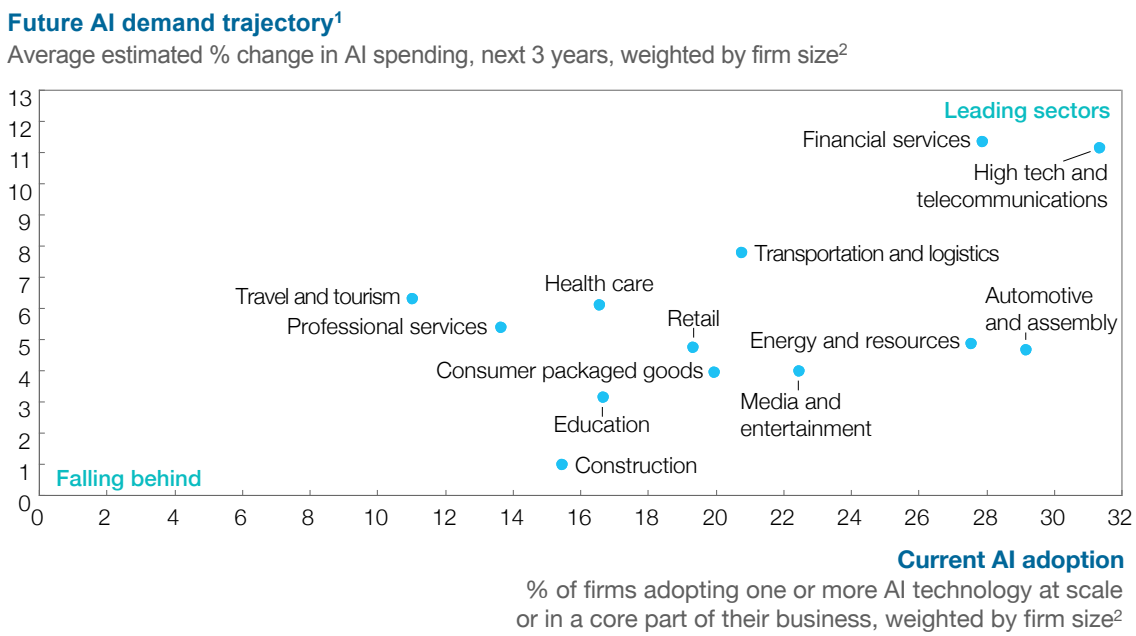
effective optimization as well as solve for objective functions (e.g. duration or cost of fuel).[5] Such technology could be directly applicable to E&C project planning and scheduling, as it has the potential to assess endless combinations and alternatives based on similar projects, optimizing the best path and correcting themselves over time.

Pharmaceutical outcomes prediction for constructability issues.

The pharmaceutical industry has emerged as a leader in investing its large R&D budgets into predictive AI solutions, which lower R&D costs in the long run, chiefly by forecasting medical trial outcomes. These applications can be directly applied to the construction industry—particularly in major projects with R&D budgets as large as those of Big Pharma—in two ways to forecast outcomes. First, predictive applications can forecast project risks, constructability, and the structural stability of various technical solutions, providing insight during the decision-making phase and potentially saving millions of dollars down the road. And second, these applications can enable testing of various materials, limiting the downtime of certain structures during inspection.

Exhibit 1

Sectors leading in AI adoption today also intend to grow their investment the most



1 Based on the midpoint of the range selected by the survey respondent.
2 Results are weighted by firm size. See Appendix for an explanation of the weighting methodology.

Source: Michael Chui, James Manyika, and Mehdi Miremadi, "What AI can and can't do (yet) for your business," *McKinsey Quarterly*, January 2018, McKinsey.com

5 For further reading on reinforcement learning, see Michael Chui, James Manyika, and Mehdi Miremadi, "What AI can and can't do (yet) for your business," *McKinsey Quarterly*, January 2018, McKinsey.com.

Retail supply chain optimization for materials and inventory management.

AI has changed the game for the retail supply chain by reducing manufacturing downtime, reducing oversupply, and increasing predictability of shipments—all resulting in impressive reductions in costs, logistical burdens, and variability. Supervised learning applications (e.g., gradient-boosting trees[6]) will become directly applicable to E&C as modularization and prefabrication become more prevalent. More projects are using off-site construction for large quantities of materials, and the need for enhanced supply chain coordination will become critical to control costs and overall cash flows.

Robotics for modular or prefabrication construction and 3-D printing.

While use of modularization and 3-D printing is advancing in construction today, there could be a longer-term opportunity to maximize the benefits of these approaches through machine learning. For example, robotics industry researchers have successfully trained robotic arms to move by learning from simulations.[7] In E&C, this application might someday be applied to prefabrication techniques and maintenance operations for oil and gas as well as other industrial sectors.[8]

Healthcare image recognition for risk and safety management.

In the healthcare industry, machine-learning methods are creating breakthroughs in image recognition to support the diagnosis of illnesses (e.g., detecting known markers for various conditions). Down the road, this technology could be applied to drone imagery and 3-D-generated models to assess issues with quality control, such as defects in execution (both structural and aesthetic) and early detection of critical events (e.g., bridge failure). These techniques could help engineers compare developing and final products against initial designs, or train an unsafe-behaviors detection algorithm to identify safety risks in project sites based on millions of drone-collected images.

Additional machine learning algorithms with potential to disrupt E&C

The number of AI solutions applicable to E&C are potentially endless. To scratch the surface, we offer a focused look at a few of the possibilities in machine learning (Exhibit 2).[9] While machine learning is but one branch of AI, its breadth of supervised and unsupervised learning techniques, as well as deep learning convolutional and recurrent neural networks, offer myriad business cases for investment.

Several use cases will be applicable across the broad spectrum of E&C stakeholders, including owners, contractors, and operators:

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6 "Gradient boosting" is a powerful, predictive machine learning technique that enables the assessment of many weak hypotheses to build a more accurate prediction.

7 Chui, Manyika, Miremadi, "What AI can and can't do."

8 *Ibid.*

9 For further information on each of these techniques, see Michael Chui, Vishnu Kamalnath, and Brian McCarthy, "An executive's guide to AI," accessed March 9, 2018, McKinsey.com.

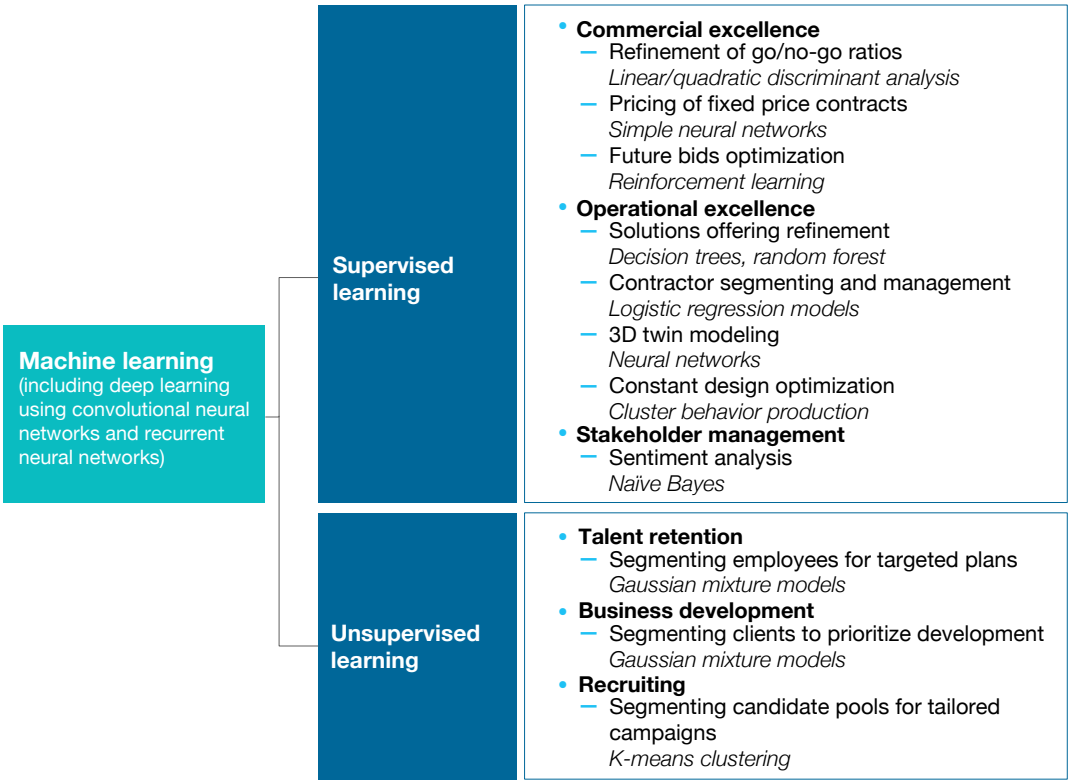
Refining quality control and claims management.

Firms can use deep-learning techniques to enhance quality control. Neural networks can, for example, assess drone-collected images to compare construction defects against existing drawings. These networks are also capable of helping owners and firms alike understand the likelihood that a contractor or subcontractor will file a claim, enabling owners and firms to proactively allocate contingencies and deploy targeted mitigation plans.

Increasing talent retention and development.

One major challenge the E&C industry will face over the coming years is attracting and retaining top talent. Leaders can tackle this issue by applying both unsupervised machine learning algorithms such as Gaussian mixture models, which can segment employees based on likelihood of attrition, and developing targeted plans to retain them. K-means clustering can identify potential candidate pools and tailor recruiting strategies to attract the right talent. AI algorithms can also help leaders locate and predict overarching talent pain points such as turnover, skill or labor shortages, and flaws in organizational design. For example, it might help forecast labor shortages for skilled craft in specific geographies, or plan for hiring or locking contracts to limit costs or project delays.

Exhibit 2 **Artificial intelligence and example business applications**



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Boosting project monitoring and risk management.

E&C stakeholders can use neural networks, using drone-generated images and laser generated data capturing project progress, to teach an AI how to create 3-D "twin models" to match BIM-generated models. These applications would dramatically reduce decision-making cycles in a construction project from a monthly basis to a daily basis—through full automation of the project scheduling and budgeting update on the combination of BIM, AI, drone, and laser capabilities.

Constant design optimization.

Owners and contractors can employ a recommender system approach (supervised learning) that uses cluster behavior production to identify the important data necessary for making a recommendation. These applications can recommend to engineers and architects the use of a specific design, such a structural solution (for example, type of connections—welded or bolted) or an architectural finishes (for example, curtain walls vs window walls) based on various criteria (for example, total cost of ownership, timeline to complete execution, likelihood of defective constructions-mistakes during execution). The end result is that owners and contractors have more information with which to make an informed decision.

Several other applications have a specific use case for E&C contracting firms:

Building commercial excellence and a competitive edge.

By assessing previous project bids and replicating elements of the successes while avoiding elements of the failures, supervised and unsupervised learning algorithms can boost an E&C firm's project win rate, enhance margins, and ensure project value. Linear/quadratic discriminant algorithms, for example, can enhance a firm's forecasting ability to estimate a lead's likelihood of being accepted (i.e. go/no-go ratio) and likelihood of closing (i.e. get/no-get ratio). Simple neural network algorithms can be used to assess the rates or lump-sum price discounts clients may be willing to pay for a project, while in the future, reinforcement learning could help optimize bids and designs based on prior successful bid decisions. These algorithms can also predict what combination of services might be most attractive to clients, particularly as firms move toward offering integrated solutions rather than traditional one-off projects.

Firm reputation and risk management.

Given the recent wave of earnings misses and project write-offs in the E&C industry, the confidence of the market and individual clients in a given firm's ability to meet commitments has dropped. Because of this shift, firms are losing project bids and the market is penalizing stock prices. Firms can apply machine learning to rapidly address market and client concerns. For example, Naïve Bayes algorithms can be employed to perform sentiment analysis on a firm's market perception and inform the launch of targeted, reputation-building efforts needed to preserve its backlog and stock price. Algorithms can also be used to profile customers based on their characteristics and desires to better target business development efforts and improve retention.

What leaders can do to get ahead of the curve and take advantage of AI

There are several steps that all stakeholders can take to get ahead of the curve in AI:

Identify high-impact use cases based on a firm's starting points.

Firms need to identify the areas of major need and what AI-powered use cases can have the most impact in the short term. Without a clear business case, ROI, and burning platform, E&C firms will be inefficient in the use of time and resources, which can create frustration, increase skepticism in the organization, and cause firms to lose momentum. Leaders should prioritize their investments based on the areas where AI can have the most impact on the firm's unique situation and need—for example, safety or talent retention—and where it will be easiest to implement in the firm's current stage of digital maturity.

Dedicate a significant portion of R&D investment to digital capabilities immediately.

Today, the E&C industry is investing roughly 1 percent overall into technology—a significantly smaller proportion than other industries, such as financial services and manufacturing. Because the impact of AI is contingent on having the right data, E&C leaders cannot take advantage of AI without first undertaking sustained digitization efforts. This includes investing in the right tools and capabilities for data collection and processing, such as cloud infrastructure and advanced analytics. McKinsey research finds that companies with a strong track record of digitization are 50 percent more likely to generate profit from using AI.

Embrace the ecosystem concept and understand solutions from other industries.

For too long, the E&C sector has operated within a vacuum. Given the move toward ecosystems discussed above, industry insiders need to look beyond sector borders to understand where incumbents are becoming more vulnerable and to identify white space for growth. Both owners and E&C firms can explore nontraditional partnerships with organizations outside the industry to pool advanced R&D efforts that have multiple applications across industries (for example, start-ups, universities, or even major players in other sectors where AI is more evolved). For E&C firms that can pursue unsolicited bids or real-estate development, such partnerships could be a way to increase data points and generate value. In addition, owners and firms can ensure corporate development teams have the talent and topical expertise to assess potential technologies with the entire ecosystem in mind.

Adapt the talent capabilities of the company.

The industry will need to reverse its trend of underinvesting in developing talent and place significant focus on hiring people from other industries with backgrounds and skill sets in AI and digital technologies. In addition, firms will need to reskill their current workforces to acquire the necessary capabilities to thrive in the digital age and provide training in necessary concepts, such as machine learning algorithms.

Change internal processes to accommodate the innovation that AI will bring.

Today, the processes critical to actualizing AI solutions—such as how to propose and implement a new idea—are handled several levels below the CEO. But top leadership needs to be involved in developing these processes and bolstering employees' flexibility to

innovate. While seemingly a simple step to take, ensuring the C-suite is influencing process development is a key enabler of preparing to embrace AI.

First movers and fast followers will be rewarded

The concrete steps outlined above can serve as an immediate starting point for firms to pursue AI. Indeed, early movers will set the direction of the industry and reap both short- and long-term benefits. Though E&C tends to lag behind by measure of technology adoption, now is the time for owners and firms to act and secure their places at the vanguard of pulling AI applications and techniques into the sector.

Photo credit: Getty Images

Construction in the cloud: An interview with Thomas Wolf, CEO of RIB Software

As construction moves into the cloud, here's what industry leaders must do to lay the groundwork for change.

Thomas Wolf

CEO of RIB,
Co-Founder & Interim CEO
of YTWO Formative

It's well known that the construction and real estate industries have been slow to adopt new technologies. But many signs point to the fact that digitization in construction is about to catch on in a big way, according to Thomas Wolf who is both the CEO of RIB Software and the interim CEO of a new RIB joint venture with supply chain solutions provider Flex, called YTWO. In February 2018, Voices spoke with Mr. Wolf about how to overcome barriers to digitization, the role of cloud technology, and what industry leaders must do to prepare for—and embrace—change.

Voices: *Please describe the opportunity for digital adoption in the construction and real estate industries. What makes these industries so ripe for digital solutions now?*

Thomas Wolf: To date, these two industries have been left largely untouched by digital technologies—only a few innovators in the world have started to embark on real digital transformations. The slow movement on technology adoption is at least in part due to the fragmented nature of these industries. A large number of small players are undertaking made-to-order construction projects—the unit size is a single project, and IT costs can only be allocated on a project level. Of course, smaller companies that consider one project at a time find it near impossible to justify large license payments for enterprise IT solutions such as 5-D building information modeling (BIM), which adds the dimensions of time and cost to 3-D rendering.

Recent developments are now upending this logic, however, and we're starting to see digitization really take off for two reasons. First, as has happened for many other industries, the costs and concerns associated with IT adoption completely change as we move to the cloud, which generally uses a monthly subscription fee model and can lower costs since hardware investment, including the installation of dedicated terminals, is not needed.

Second, the industry's competitive frame of reference is changing. Up until very recently, construction and real estate companies operated almost exclusively in a local sphere. But Google, Facebook and potentially Amazon, have all indicated plans to move into real estate development, making it a more global landscape. How long will it be before these corporate giants start competing in real estate development? For example, could we imagine a business model where apartments are provided at a lower price if tenants agree to share their data? We have seen similar business models emerge in health insurance, where the data gathered by fitness trackers allows consumers to get a discount on their health insurance. Big changes will likely need to occur before industry players can hold their own with such huge companies that use data-driven business models to reduce costs.

The good news is that a new generation of talent is now moving into the industry, and they're eager to experiment with digital solutions. The advent of 5-D BIM as well as cloud computing, big data, and artificial intelligence (AI), creates the potential to transform the construction and real estate industries into the most advanced industries on the planet. We have reached a technological tipping point.

Voices: *What are some of the most common barriers you've observed to companies embracing digitization? What demonstrable steps can companies take today to foster innovation and support the adoption of new technology?*

TW: Aside from the fragmented nature of the industry, probably the biggest barrier to technology investment is the fact that C-level management in construction and real estate is generally uncomfortable with technology discussions. While terms such as digitization, Internet of Things (IoT), and BIM may be familiar, many top managers at construction and development companies don't have a clear sense of the true potential of these technologies.

Of course, organizations looking to adopt new technology need strong leaders who are both willing to press for change and able to articulate a vision for the desired future state. But leaders must thoroughly understand the technologies before they can accomplish those goals. So, one clear step that chief strategy officers or chief technology officers can and should take now to accelerate the pace of digital transformation is educating the C-suite and the market. The C-suite must support and be fully assimilated in the transformation. Transformations are painful and are only achieved through clear targets and incentives, which the C-suite must understand and define for the organization.

Once that barrier is surmounted, as is true for any change management effort, those C-level visionaries must then convince and inspire workers throughout their organizations to abandon their print-outs and instead adopt new ways of working—on computers; mobile phones; augmented or virtual reality (AR/VR) equipment; or even drones. In our experience, dedicated digital pilots—projects that are ring-fenced from the rest of the organization and that are completely run in the new, digital way—are a great way to convince technology skeptics. Such projects are best executed under the direct lead of whomever is charged with formulating and implementing a company's digital strategy, usually a chief strategy officer or chief digital officer. And the new digital undertakings need to be nurtured and internally promoted through concrete use cases.

Voices: *In the technology industry, some of the most successful startups have become industry giants by collecting and analyzing data to distill new insights. What will it take for the construction and real estate industries to seize the opportunity?*

TW: We spend a good deal of time explaining to industry leaders why construction and real estate firms must capture data *at an enterprise level* to get to the "big data" that can eventually lead to game-changing insights. Today, however, the data that are captured, if at all, are generally only at a project level. Systems connecting information about suppliers, sub-contractors, equipment and material across the entire enterprise—not just on a project-by-project basis—are few and far between. We envision a completely new way of executing projects, particularly in the residential housing market where we see great urgency. Three million people move into cities every week. Tackling urbanization with a smarter, quicker, and more cost-efficient way to build housing is a social as well as a technological challenge.

New technologies change our way of working and our way of thinking about how we build. But to change mind-sets, many construction industry executives must start with a clear understanding of what is possible. Knowing the potential applications of 5-D BIM, and how it can affect not just what developers do in the office but also at the construction site, is absolutely necessary to executing a digital strategy and seizing this opportunity.

The cloud will be hugely important in the next frontier of digitization for the construction industry. The accumulated knowledge in the construction sector goes back centuries, and the industry is unique in its tradition, culture, expertise, and processes. It combines art (the work of the architect) with engineering (the work of the contractor) with vision and financial expertise (the work of the developer or owner). Construction therefore needs a *vertical* cloud to meet the needs of the existing ecosystem. While most cloud solutions are for general purposes (such as collaboration and file storage), a vertical cloud is customized to the specific needs of an industry. In the construction and real estate industries, a vertical cloud may contain solutions from clash detection (where design elements occupy the same space) to model management, collaboration, quantity take-off (exactly what materials and labor are needed), estimation, scheduling, site management, and others. This allows firms to focus their resources less on managing data infrastructure and more on the core business of building.

So, as a first step companies need to join a vertical cloud. Over the coming years, the amount of data generated by each construction project will grow by leaps and bounds, only making a vertical cloud a more valuable asset to help companies distill actionable insights from this data. We believe that the right cloud-based solutions already exist for this purpose. For example, we have recently partnered with Microsoft to launch the first dedicated cloud for construction and real estate. We have no doubt that cloud platforms will help construction industry players all over the world gather actionable insights and create data-driven business models.

Voices: *Looking across the construction and real estate industries, what components of a basic suite of technology are likely to have the most significant impact?*

TW: There are two ways of looking at this question. First, consider tools that can support different phases of the construction lifecycle. We have seen exciting applications of AR/VR in both pre-fabrication and on-site, for example. This technology can guide workers in carrying out work processes that they are unfamiliar with, and thus help address the shortage of skilled labor that we see in construction in many countries. It can also facilitate tracking on-site progress by offering a quick, visualized way of capturing the data related to work that has been carried out throughout the day.

But tools only help in one work step of a construction project. To truly transform our way of working and thinking in the industry, we must focus on the whole process and on the enterprise to come to actionable big data—and that's what 5-D BIM does. This software allows the design to guide the entire construction process. Designers, engineers and all other project stakeholders can work collaboratively out of one single source of truth.

Voices: *What advice do you have for CEOs just beginning this digital innovation journey?*

TW: CEOs just beginning the digitization journey should work closely with their dedicated IT team or technology partner to evaluate and ensure that their digital strategies match their organizations' vision and culture. A comprehensive training system should be provided to fully support the staff migrating from the traditional way into the new way of thinking and working. The leadership should also be adaptive—open to feedback and new ideas so that they can make necessary changes during the implementation and achieve the best possible result.

Indeed, leaders in the construction and real estate industries will need an open mind-set and a willingness to change. A digital transformation requires adopting not just a new technology but also new methods for thinking and working, and CEOs must lead by example.

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.

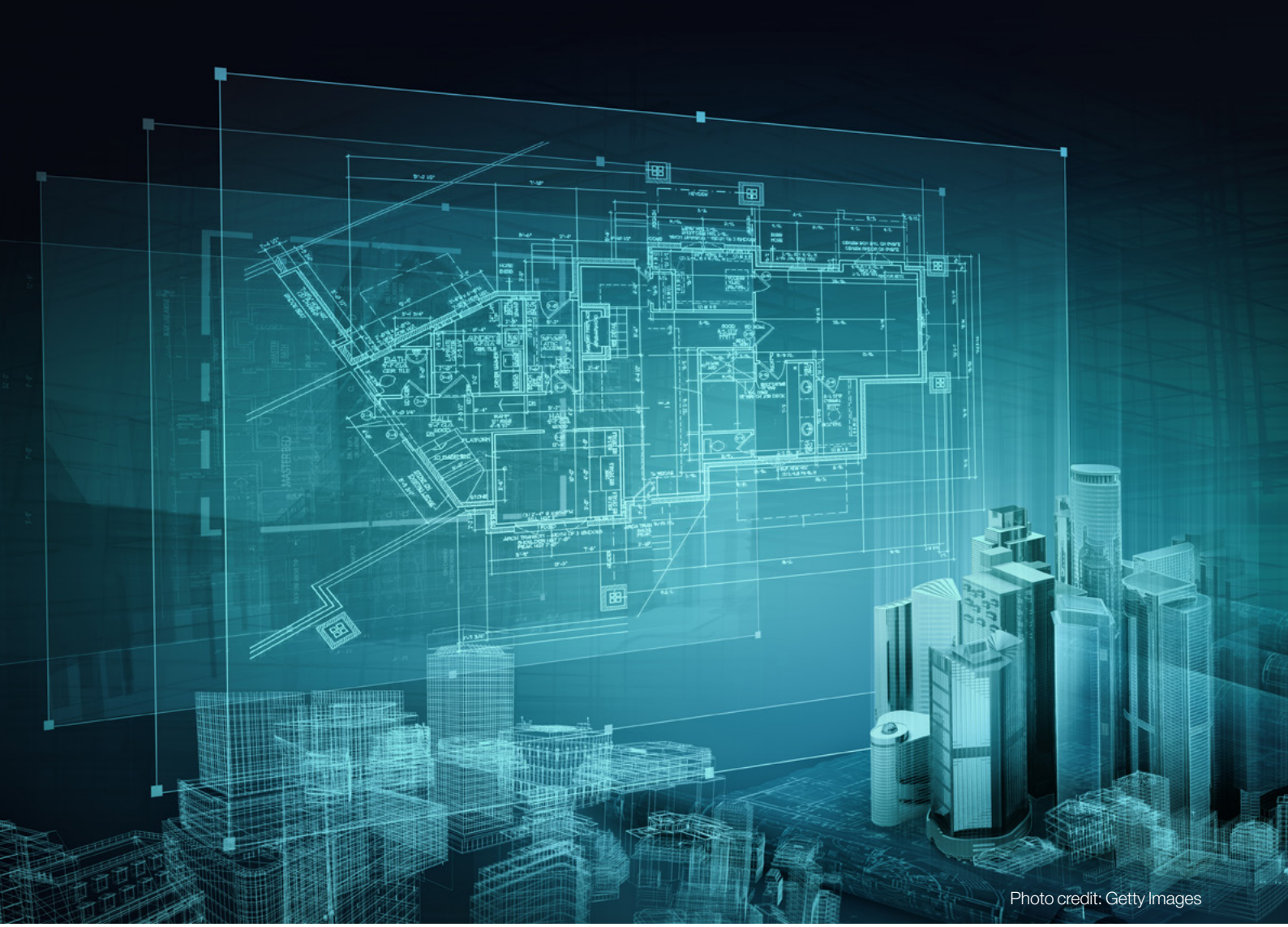

Photo credit: Getty Images

Daring to digitize: Improving productivity on capital projects

With digital solutions poised to disrupt capital projects, companies must overcome their long-standing reluctance to apply these tools. Here's how.

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Construction's under-digitization has become a well-known industry lament—as have the resultant lags in productivity and delivery. The root causes are many but one looms large: all stakeholders in the capital-projects ecosystem—project owners, contractors, and subcontractors—have resisted adopting digital tools and platforms.

Their reluctance does not stem from an absence of solutions—construction-technology firms garnered $10 billion in investment funding from 2011 through early 2017. Instead, the problem lies with planning and execution. Some companies limit their investment in digital solutions because they cannot identify tools that address their major pain points. Others struggle with implementation, often losing momentum after the pilot stage. But leaders can overcome these issues through a new approach to digital strategy that emphasizes business value.

A multi-faceted approach to digital innovation

In a recent analysis of 22 major industries, construction came in second to last for overall digitization. This troubling statistic largely explains why the sector's productivity is now about half that of the total economy. But our research shows that if companies begin using available digital tools, they could reduce project costs by up to 45 percent—not enough to close construction's productivity gap, but enough to make significant strides.

As leaders wade through the wealth of digital offerings at their disposal, they should first determine their most acute pain points, as well as the opportunities they would like to pursue. Managers should then classify tools on two levels (Exhibit 1):

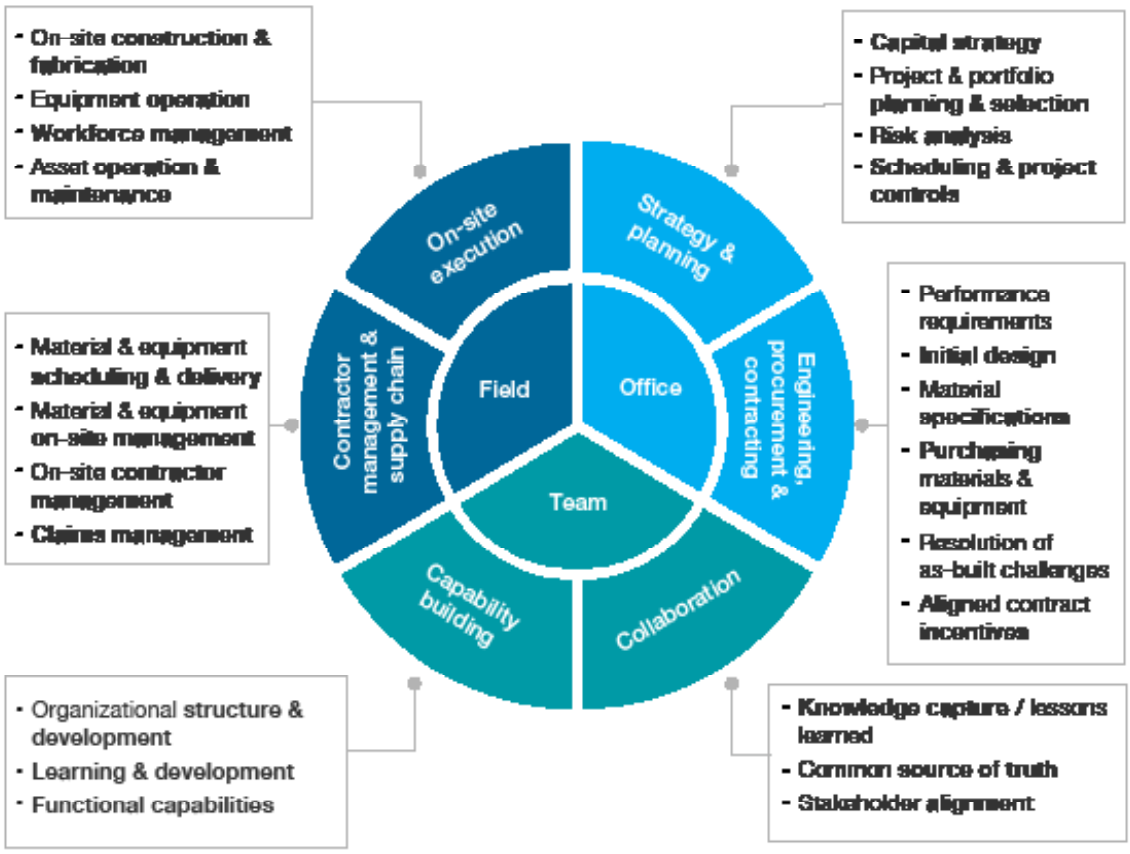
- Clusters. Most digital tools fall into one of three clusters: on-site execution, back-office integration, or digital collaboration. As their names suggest, tools within on-site execution and back-office integration are used to add value in these settings, while collaboration tools can be used in any setting.

- Tasks. Within each cluster, companies should take the categorization a step further by classifying tools based on the specific improvements that they facilitate. Tools will again fall into major groups: within on-site execution, for example, most tools assist either with execution in the field or with tasks related to contractor management or supply-chain management.

Although owners and engineering and construction (E&C) companies face unique challenges that will influence tool selection, solutions in five areas can benefit virtually all organizations:

- Digital-project controls and work-front management. Delays and cost overruns often happen because stakeholders monitor performance based on different data sources, resulting in conflicting progress reports. A cloud control tower helps eliminate these issues by providing real-time information about critical activities in a central database that all employees can access.

Exhibit 1 **Companies should adopt a two-level system for classifying digital tools.**



- Capital-portfolio management. Software programs can assist with portfolio management by tracking expenditures, monitoring progress, and flagging potential issues that could raise costs or extend timelines. Some software programs also help with decision making, such as those that compare projected results for two potential portfolios.

- Next generation 5-D building information modeling (BIM). Contractor management is difficult because documentation and project data tend to be scattered across disparate sources. 5-D BIM—the combination of 3-D physical models of buildings with cost, design, and scheduling data—can improve execution. For instance, 5-D BIM reduced construction time by three to five months at an airport project by providing faster clash detection and better visualization of the proposed structure.

- Advanced analytics. Machine learning, data-ingestion engines, and innovative pattern recognition enable managers to rapidly sort through millions of data points. With this capability, companies gain greater insight into both performance drivers and risks. In some areas, advanced analytics may produce savings of up to 25 percent.

- Next-generation surveying and prefabrication analysis. Virtual-reality tools help users view and interact with designs and prototypes as if they have already been constructed. Similarly, advanced surveying tools help users understand as-built conditions and compare them with designs.

These five capabilities provide many benefits, but companies may not capture maximum cost reductions from digitization until they implement complex solutions that require greater digital skills, including those that rely on autonomous vehicles, automated construction processes, and 3-D printing.

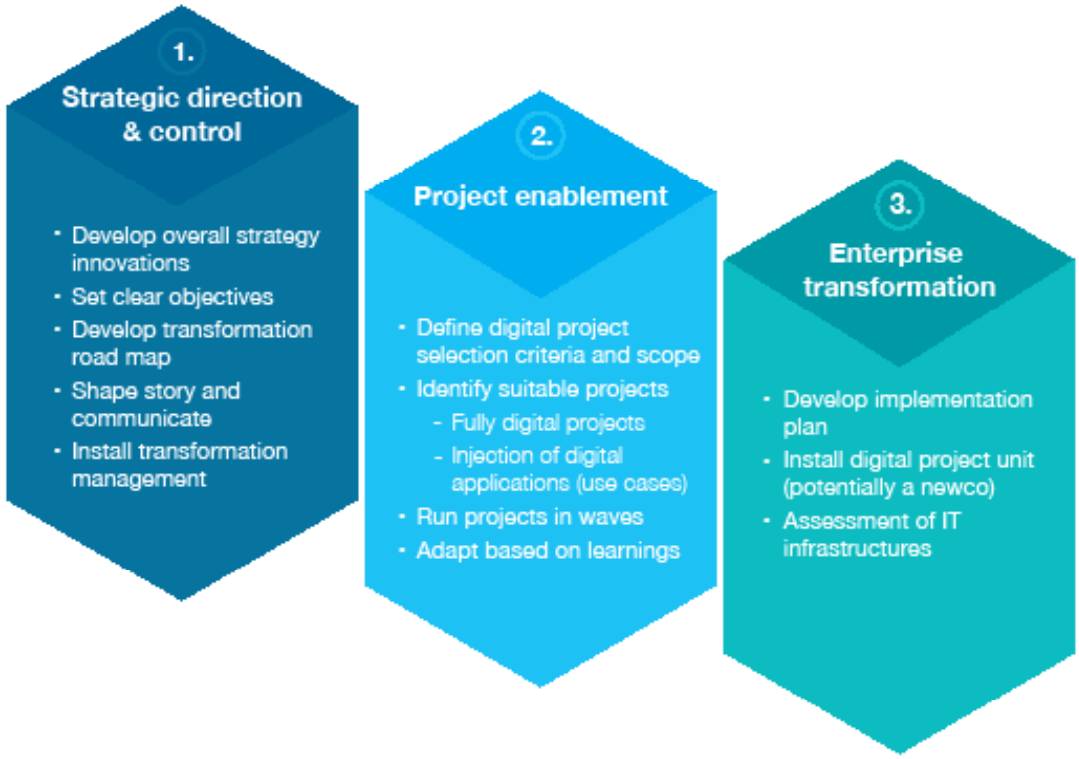
Three building blocks for digital leadership

Digital initiatives often fail because project leaders in the field are reluctant to implement new technologies, believing that they will increase costs and risks while conveying few benefits. To counter this perception, a company's CEO and board members must take ownership of the digital transformation from the outset, focusing on three building blocks: strategy (linked to business value), project enablement, and enterprise transformation (Exhibit 2).

1.Strategic direction and control

CEOs and board members should create a comprehensive digital strategy, communicate it throughout the organization, and develop a transformation road map with tangible

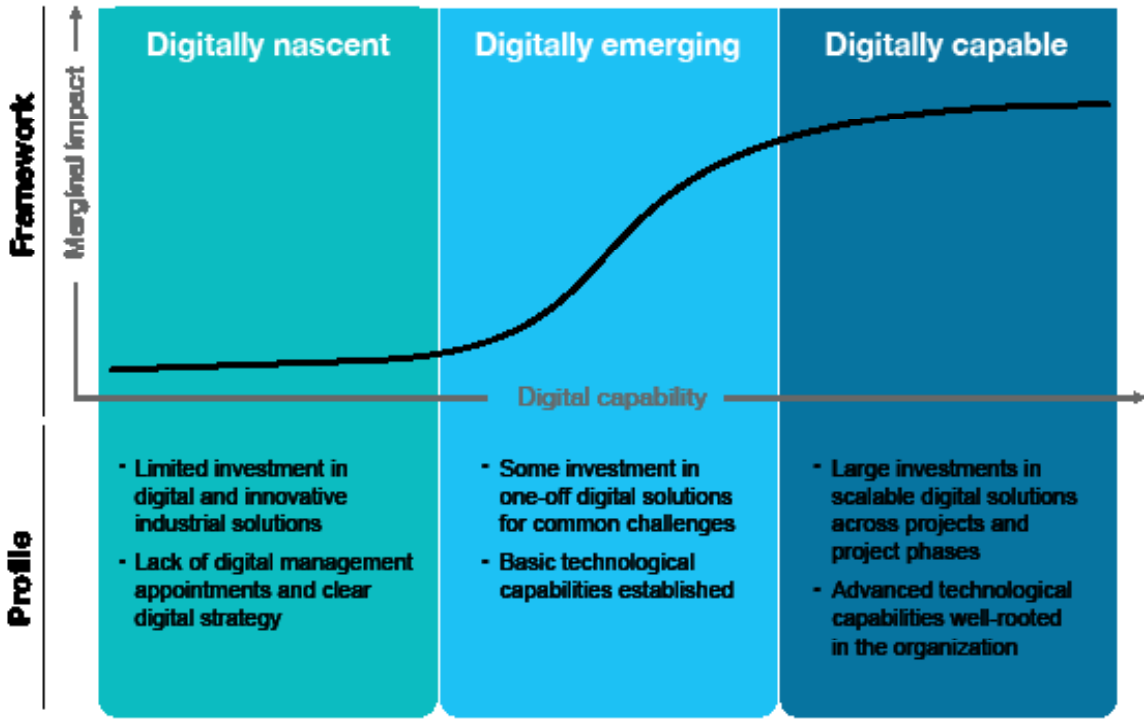
Exhibit 2 **In a digital transformation, leaders should focus on three building blocks**



objectives. They should also install a transformation management team that has decision-making authority and the full support of senior leadership.

When evaluating potential solutions, companies should prioritize investments that address their greatest needs. They must also realistically assess their company's digital capabilities—an analysis that will prevent them from selecting tools that grab headlines but are too complex for their organization to implement. Generally, companies fall into one of three categories based on their investment levels and experience: digitally nascent, emerging, or capable (Exhibit 3).

Exhibit 3 **Companies must understand their current digital capabilities to design a digital journey that will address their key challenges**



A company's digital maturity will help determine near-term priorities. For instance, a digitally nascent company might deploy basic tools that increase collaboration and transparency about a project's progress, while a digitally mature company might focus on field tools that fundamentally change operations, such as on-site 3-D printing or autonomous vehicles.

2. Project enablement

To avoid overburdening staff or budgets during the early wave of a digital transformation, companies should focus on a limited number of projects. Managers should define and

manage the scope of each digital initiative, noting specific areas where it should generate improvement. After the first projects have launched, companies can embark on additional implementation waves that encompass more projects and generate greater impact.

3. Enterprise transformation

Comprehensive digital transformations—those that reach all business units and levels—are difficult to launch and maintain across project teams. To generate value without disrupting the core business, companies should consider establishing a "Newco," a business unit with the specific skills and resources to facilitate digital change across multiple projects. Newcos—successfully used by the banking and finance industry to transition to digital—can ensure that agile and lean processes are in place to support new tools, and they can scale up innovative programs quickly. As other groups see the value that Newcos generate, they will be more likely to appreciate and accept digitization.

Strong management will be essential for any digital initiative, and companies may choose different approaches. Some may appoint a chief innovation officer to handle all initiatives, while others may delegate responsibility for different tasks to business-unit leaders.

Another crucial prelaunch step involves creating implementation plans that describe how the first few digital projects should proceed, with specific performance indicators and milestones. While developing these plans, companies should reassess their technology infrastructure and determine if it will support their desired goals.

Finally, companies must consider new pricing strategies. They may need to emphasize the benefits of digital solutions and innovative approaches to customers at the project-proposal stage. Without buy-in from all major stakeholders on the client side, it will be difficult to drive adoption.

Tips for maintaining momentum

To stay on track, capital-projects leaders should create new organizational structures and processes that promote innovation—either within a Newco or within the existing business. Leaders should assign responsibility for developing and coordinating execution of the digital strategy to specific groups or individuals. In tandem, they must shift performance-management and capability-building processes to place more emphasis on digital skills. Outside hires, such as chief technology officers or data scientists, may be essential to fill some talent gaps.

Many businesses will also need to revise their long-standing processes and timelines. For example, most companies complete the project planning phase relatively quickly, but they may now need more time to get cloud control towers and other tools up and running.

Digital tools are not a silver bullet for construction's productivity issues, but they represent the greatest improvement lever available. Companies that are slow to digitize, or that lack a well-structured transformation plan, could soon lose ground to bold leaders and fast movers who aggressively support digital programs.

Read an extended version of this article on McKinsey.com: *Navigating the digital future: The disruption of capital projects*.

London Visions - created by Squint/Opera, commissioned by the Museum of London, 2018

How virtual and augmented reality will shape the future of built environments

Stakeholders serious about garnering support for infrastructure projects can turn to technology to tell the story and highlight value.

Jan Bunge

Managing Director,
Squint/Opera

The evolution of virtual and augmented reality (VR, AR) in the past few years has unveiled a wide variety of use cases for the infrastructure sector, from design to marketing. However, the technology's former incarnations—defined by low-quality imaging and cost-prohibitive expenses—have led to barriers to widespread adoption. Jan Bunge of Squint/Opera, an agency focusing on design, animation, and interactive exhibitions, discusses the evolution of this technology, the ways its new form will change how contractors and project owners can win community and investor support, and how it can redefine internal process to get much-needed infrastructure plans off the ground.

VOICES: *What role can VR and AR technology play in communicating infrastructure projects?*

Jan Bunge: VR and AR are revolutionizing the way we approach infrastructure projects. When it comes to imagining the future, we each have our own set of ideas in our heads. The challenge for anyone involved in creating buildings, infrastructure, or cities is to unlock the vision so everyone can share it, shape it, agree upon it, and deliver it. But it's difficult to communicate complex ideas in a short amount of time and make sure people understand the core, unique selling point of the proposition. You need to get people excited about projects and places that don't yet physically exist. Success requires compelling storytelling.

In the past, we relied on two-dimensional plans, drawings, and imagery, or perhaps three-dimensional models to convey a sense of the future project or place. Three-dimensional models offer a big leap forward in understanding, and so too do the fantastic digital renditions of buildings and places, but they still require a good eye to interpret. And even if we manage to create the best project descriptions, images, films, and physical models, we still need the viewer to make that big conceptual leap into thinking themselves into the space and imagining how it would feel.

Now, thanks to VR and AR, we have the ability to manipulate perception to such an extent that we can enter another type of "reality"—and this changes everything. For the first time in history it is possible to get a feel for a space, to walk through it, before it is built. Simulating the visual experience as well as the actual soundscape facilitates an emotional connection with the space. People can get a sense of the volume and scale, the ways the spaces are linked, the views, the material palette, the way buildings sit in the landscape, and even the way the sun travels around the spaces during the day. And, not surprisingly, this capability will change the way we design these projects as well, because we can adjust to take ever greater advantage of views, natural sunlight, finishes, and so forth.

VOICES: *Can you give an example of how VR has altered the path of a project?*

JB: One recent example of using VR and AR to communicate an idea was during a community meeting about a new bridge river crossing. Community members expressed anxiety that the proposed new structure was too big and would be too prominent in the landscape. A consultation day involved the use of VR headsets so people could see different

bridge designs and how they would sit in the landscape. In the end, participants voted in favor of the largest structure on the grounds it would become a beautiful, local landmark.

It's human nature to be cautious of change, and I'm convinced that outcome would never have been possible using only two- or three-dimensional plans and drawings.

VOICES: *Why now? What has changed to make VR and AR more viable technologies for use in infrastructure?*

JB: A couple of years ago there was resistance to using VR; it was expensive, the images were less sophisticated, and the headgear was clumsy—the size of a motorbike helmet. But the barriers are gradually diminishing; the assets are becoming less expensive, higher quality, and more agile. The best way to convert anyone who is skeptical is to give them a demonstration of how the technology works—they'll be onboard very quickly.

And with the likes of Amazon, Facebook, and Google—as well as entire industries such as health care and the military—heavily invested in VR and AR technology, we are seeing fast-moving, constant improvement in adoption across the board. As the tech evolves, and production costs come down, we can expect VR and AR to become part of the everyday design and consultation process.

VOICES: *How is this technology helping bridge the bankability gap in funding infrastructure?*

JB: While it is widely accepted that there is an infrastructure gap (demand far outstrips supply in many cities), it is also acknowledged that there is plenty of private investment money that could help much-needed projects get off the ground. Many of these private investors may be new to the infrastructure sector, and companies can use VR and AR once again as a tool to explain the proposition in a compelling way. Financial projections will be part of that package, but the appeal is stronger when people can "see" what they are investing in.

VOICES: *How do VR and AR fit into a broader vision for how the infrastructure and real estate sector could function in the future?*

JB: We see the use of VR and AR becoming firmly embedded in every stage of the process of all types of new developments in the future. It's useful in developing concepts, helping inform design, evolving ideas with city administrators and developers, explaining future projects to communities, and supporting marketing and sales efforts.

In real estate, for example, we see the possibilities of buyers being more proactive in the process of designing their own spaces. Developers can offer people the opportunity to virtually explore unbuilt properties and make choices about things like the style of bathroom or kitchen. In future, that experience could be richer and deeper. Why not specify the exact materials, move walls around, import your furniture to see how it looks, and experience how the space will look and feel—and even smell? And it will be possible to do this with a friend

or partner even if they are in a different country; you can meet in the virtual space and “walk” around together.The same experience of course applies to train carriages, stations, or any other parts of the built environment. I could see a future where every large infrastructure project kicks off with a project expo where all stakeholders (planners, investors, and local residents) could come and explore the whole proposal. Participants could walk through spaces, fly over and around the whole scheme, and enjoy the views. I believe when people can understand the future they can get excited about it.

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.

How advanced analytics can benefit infrastructure capital planning

Asset owners are lagging other industries in data analytics. Now's the time to get going.

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Advanced analytics—the ability to generate valuable insights from large amounts of data—has emerged as a powerful tool to understand and learn from past performance as a guide to more accurately predict trends. Analytics creates value when big data and advanced algorithms are applied to business problems to yield measurable improvements. By identifying, sizing, and prioritizing the biggest opportunities, businesses can create an analytics strategy that generates value.

Although advanced analytics are increasingly employed by infrastructure players in both the private and public sector, the industry still tends to lag others such as retail, financial services, and automotive in embracing its comprehensive use across the project life cycle. To the extent these methods are applied, it is predominantly in the project-delivery phase rather than integrated into capital planning. As a result, many asset owners experience weaker capital productivity than what we see in other sectors, as they are making major decisions based on primarily qualitative, rather than quantitative, factors.

Incorporating advanced analytics into the capital-planning phase can radically improve the ability of owners to make decisions based on the expected performance of their existing infrastructure. For example, it can enable them to form more refined asset lifecycle curves, which allows them to align investments with needs in design, construction, operations, and maintenance. It can also help owners and operators generate deeper insights and value on maintenance versus replacement decisions and asset-longevity trends.

Taking advantage of data-driven methods could help owners free up capital—we've seen portfolio savings of 5 to 15 percent—and permit them to reallocate money to more attractive projects. In this article, we outline how advanced analytics can benefit infrastructure owners when applied to capital planning and describe a methodology to pursue this rich opportunity. Those that seize the moment have a chance to become leaders in the field.

Taking advantage of the data-driven environment

Owners of complex assets are challenged to make use of the vast amount of data now being gathered by sensors and sources across their networks. Powerful analytics tools are readily available and can assist by creating a visualization platform and using machine learning to help spot patterns in the data.

The ability to predict the likelihood of a given event can then inform the organization's capital-portfolio-development process and help identify underlying life-cycle drivers, including which preventative mitigation measures it must invest in.

Another key benefit of advanced analytics is the level of precision it enables in an owner's decision making. While traditional decisions may have focused on whether to maintain or replace an asset entirely, advanced analytics can help owners prioritize replacement or repair of specific components rather than a complete asset.

For example, the use of sensors can allow a department of transportation to identify bridges that require a complete reconstruction and others that need only one or two new

girders to replace those presenting structural issues. In one case, the South Carolina Department of Transportation has a Federal Highway Administration grant to evaluate the value of structural-health-monitoring technology to complement visual inspection and other information regarding specific bridges.

Another emerging use is in the railroad industry, where sensors monitor track geometry, rail corrugation, and track-surface measurements, facilitating maintenance and long-term investment decisions. For one railway company, the use of existing-condition data as a predictor of required maintenance helped save more than 30,000 man-hours a year and allowed the company to redirect $20 million of annual engine-overhaul spending toward capital-replacement investments.

Integrating advanced analytics into capital-planning decisions

Infrastructure owners generate vast amounts of data. But the data are often isolated, unassimilated, and underused. In some cases, the data are employed for narrow analyses and not aggregated to enable a broader understanding of how an asset is performing. Three pillars support the integration of advanced analytics into the capital-planning process and development of useful insights for asset-portfolio owners:

- refinement of the current capital-planning process: integrating predictive insights and establishing structured, repeatable advanced-analytics processes using diverse data sets
- use and integration of leading-edge systems: identifying and aligning the data systems to inform the model and applying sophisticated advanced-analytics tools and systems
- commitment to build capabilities: ensuring that the appropriate people and skill sets are in place to promote model development and use across the portfolio

Below, we explore how infrastructure-asset owners can move ahead in these three areas.

Incorporating analytics into the capital-allocation process

Capital-allocation processes will vary among organizations. However, we believe a best-in-class approach uses evaluations of asset health in the development of the overall strategy.

Often, the decision to replace or refurbish an asset is influenced by broad, historically established industry benchmarks that are often conservative, advocating early replacement to rightfully avoid failure. However, using advanced analytics allows managers to better understand “instantaneous asset health” by predicting expected asset performance using multiple indicators compared against a wide and deep data set. For example, one asset owner employed predictive models and ground-movement sensors to identify anomalies during tunneling under a city. The approach enabled the asset owner to install a more

efficient sensor array and monitoring system that enhanced its ability to conduct predictive maintenance and thus reduce overall long-term capital investment.

Defining the advanced analytics process

When embracing the use of advanced analytics in capital-investment decisions, the goal is to capture and use all applicable data sources both internally and externally available to develop a robust predictive model.

Success employing these techniques is largely dependent on the ability of organizations to change the way they work and pilot innovation with an open mind. We have found that a three-phase approach is the most effective in developing the tailored predictive systems and integrating into an owner's ecosystem: design and data ingestion, proof of concept, and integrate and scale.

Design and data ingestion

During the initial phase of incorporating advanced analytics into the organization, a structured database of all likely internal and external data sources is developed. The early evaluation of the data set provides a first assessment of likely drivers affecting overall asset performance. Sources of data would include the following:

- design and construction records
- operational records
- maintenance and recurring capital-expenditure records
- inspection reports
- incident reports
- historical failure data
- expected remaining life
- seismic data
- historical weather data
- interviews
- previous criticality assessments

Owners need to understand that data are an asset (in fact, tech companies typically build business models around it). As data ingestion becomes more sophisticated, owners should

strive to collect macro and micro data about their projects throughout the life of the project development and execution cycle, as well as link it to external market trends.

Proof of concept

The second phase is supported by the outputs from the initial model design and data-ingestion process. A range of tools can be used to model past events and identify a set of quantified performance drivers to predict future performance. Some of the analytical approaches include proportional-hazard modeling, incipient-failure detection, and probability-distribution functions.

The output from this phase enables a dynamic predictive model for critical assets to identify failure mode, performance drivers, and life-cycle timing.

Integrate and scale

The advanced-analytics model is constantly updated to provide real-time predictions of asset performance. Having established the initial model, other predictive models can then be created to estimate likely performance of other asset types and subsystems within the capital portfolio. Typically, the systems, processes, and capabilities developed up to this point are used to efficiently scale the use of advanced analytics across the remainder of the infrastructure portfolio.

Deploying and integrating leading analytics systems

Significant thought goes into which systems and tools to deploy when developing a predictive system. The systems and tools should be integrated with existing information-technology systems.

Commitment to build capabilities

The third pillar supporting the integration of advanced analytics into the capital-planning process is ensuring that the right people and skill sets are in place. Owners should invest in professionals who can develop enterprise-level analytics.

This will likely require investment in all aspects of talent development, including recruiting, hiring, and training. In addition, and perhaps most important, organizations will likely need to retool their systems, processes, and culture to reflect the value of advanced analytics. Leaders must make clear that analytics is not a marginal capability; on the contrary, they must ensure that its practitioners have the authority and organizational reach necessary for impact.

• • •

Infrastructure-asset owners have been slow to introduce advanced analytics into their capital-planning process. But they can take heart from the experiences of adjacent

manufacturing industries, where the introduction of advanced analytics has led to improved returns on invested capital. Incorporating advanced analytics into the capital-portfolio-planning process could lead to more efficient deployment of capital in both the private and public sector, enabling owners to fund additional projects across their networks.


Photo credit: Getty Images

How utilities can speed their digital transformations

Utilities have found it hard to scale their digital pilots up to full digital-transformation programs. Adopting digital ways of working, adding talent, and modernizing IT will speed their efforts to reinvent themselves as digital enterprises.

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For utility companies, transforming operations and systems with digital technologies and ways of working can create substantial value: a reduction in operating expenses of up to 25 percent, which can translate into lower revenue requirements or higher profits. These prospects have led utilities to launch all sorts of digital-transformation efforts, such as scheduling maintenance with predictive models and optimizing customer experiences.[1] Yet few of the digital projects we've observed at utilities have created momentum for comprehensive reinventions.

That's understandable. In our experience, digital transformations at utilities are often inhibited by these three issues:

- The typical utility has built its working methods around safeguarding large, long-lived assets and minimizing operational risks. This mind-set makes utilities cautious about embracing digital ways of working that involve constant experimentation.

- The popular perception of utilities as analog-era companies makes it hard for them to attract talent to fill digital-economy roles, such as data scientists.

- Utilities often have complex legacy IT environments that slow down innovation.

These conditions aren't easy to overcome, but some utilities are showing that it can be done. Here's how leading utilities are accelerating their digital transformations (exhibit).

1. Adopting digital ways of working

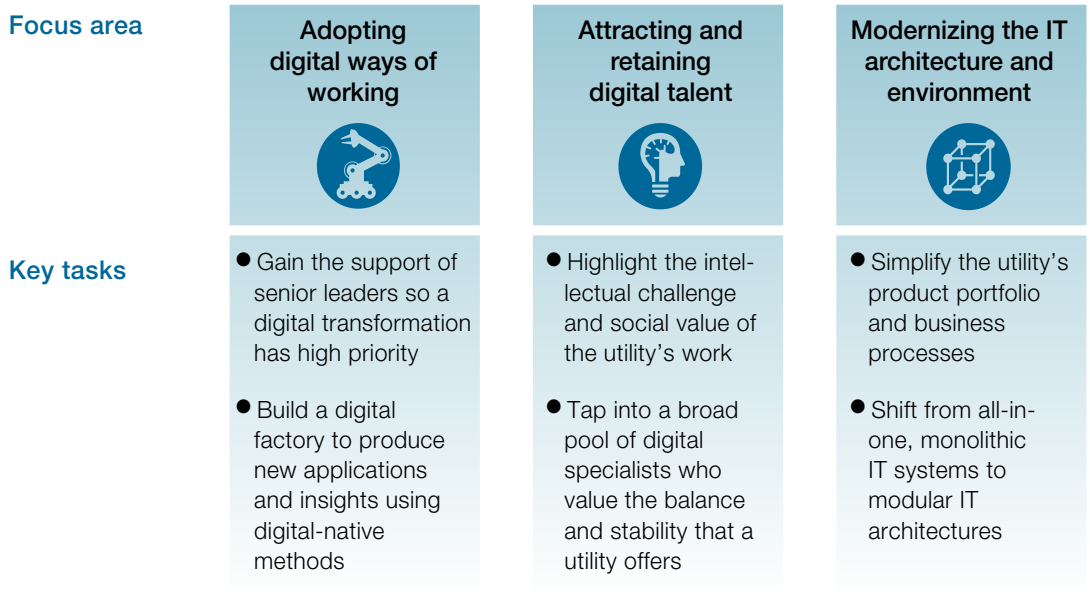
The conventional wisdom in the sector is that utilities need to be stable, reliable, and secure above all. We agree that these are important virtues. However, utilities face fresh threats as challengers learn to operate and innovate at high speed. To keep up, utilities need to increase their agility—their capacity for sensing challenges and opportunities and for quickly mobilizing the organization in response. Greater agility can make assets safer and more reliable by enabling utilities to anticipate, detect, and resolve problems faster. Making that happen, though, requires support from senior leaders and, ultimately, the entire company.

Utilities may face challenges when it comes to persuading senior leaders, many of whom have spent almost all of their careers in the sector's traditional environment, to adopt digital ways of working and prioritize a digital transformation. Executives who are unsure about the need to digitize would do well to spend time at digital-native companies and digitally transformed incumbents. Observing their operations firsthand can assuage concerns that digitization will derail fine-tuned processes and systems. And learning from fellow executives about the pressure they face from digital competitors should remove doubts about whether utilities ought to go digital.

1 For more, see Adrian Booth, Niko Mohr, and Peter Peters, "The digital utility: New opportunities and challenges," May 2016, McKinsey.com.

Exhibit

Utilities can accelerate digital transformation by focusing on changes in three main areas.



McKinsey&Company | **Source:** McKinsey analysis

Even in the best situations, with executives who fully support digitization, it can take years for an entire utility to embrace the methods of digital-native businesses. To refresh their working styles, some utilities have acquired or partnered with smaller digital businesses or start-ups, but this rarely catalyzes enterprise-wide change. A more effective approach is to set up an in-house digital factory devoted to producing digital applications by using the latest technologies and ways of working.

While such a digital factory can be modest in size at the outset—20 to 50 people—it should have a strong, well-positioned leader and a diverse staff of product owners, designers, software architects, scrum masters, data scientists, and developers. It also needs to be as autonomous and self-contained as possible so it can operate at a faster speed. Achieving a high level of autonomy might mean liberating a digital factory from dependencies on enterprise-level processes like hiring, planning, and budgeting.

2. Attracting and retaining digital talent

As a digital factory proves that it can deliver new products, it should continue to add staff and tackle more assignments, with the aim of working on all the value pools the utility wishes to address. Because most utilities have a major digital-talent gap to close, it is not uncommon to triple a digital factory's headcount within a year (or add more factories) while gradually replacing external contractors with internally trained colleagues or new hires.

This type of scale-up requires utilities to enter the competitive market for digital talent with a sense of urgency, especially because they are seldom seen as innovative, cutting-edge businesses. We've seen some utilities vie successfully for digital hires by playing up the intellectual challenge and reward of the utility's digital agenda. Utilities can highlight their socially valuable mission of providing a community with reliable energy, and show that their digital jobs have more meaning than jobs at a lot of other companies. For instance, one European utility presents its approach to digital technology as an important part of its efforts to lower its environmental impact—and it has success stories and a generation portfolio to back up its claims.

Another digital-recruiting tactic that utilities have used successfully is to go after a broad, diverse talent pool. While there's some truth to the stereotype of the young, single-minded software developer who thrives on energy drinks, 16-hour workdays, and a high-pressure start-up environment, plenty of digital specialists value a shorter workday and the stability of a large, established company. Utilities can typically provide both.

Finally, some utilities have chosen to partner with nearby universities as a way of sourcing digital talent and fresh ideas. To attract graduates in digital fields, one European utility has taken practical measures such as sponsoring sector-relevant courses and research, providing students with internships, and allowing managers to take sabbaticals from their utility jobs to teach.

3. Modernizing the IT architecture and environment

Most utilities have managed their IT architectures and environments much as they have their physical assets. Utilities were early adopters of large-scale software packages that offer maximum stability and performance, which they customized as their requirements outgrew the systems' standard features. Many of those systems have now been in place for decades, becoming bigger, more cumbersome, and harder to maintain.

This state of affairs severely limits the ability of utilities to adopt the modern technologies and flexible IT-management practices of digital businesses. Since complex, monolithic IT systems can take five or more years and hundreds of millions of dollars to replace, utilities should modernize their IT architectures and environments progressively.

A necessary first step is to simplify the utility's product portfolio and business processes. As regulations and customer needs have evolved, many utilities have seen their offerings (and the corresponding operational requirements) proliferate. Winnowing down a bloated portfolio makes it easier for utilities to modernize their IT architecture by reducing the number of functions that software must undertake. One European utility's portfolio comprised thousands of products and services, each of which put unique demands on the IT architecture. After the company decided to allow only offerings that can be supported by one of four variants of back-office processes, it reduced its portfolio to 150 offerings that still met 95 percent of its customers' needs.

A core tenet of efforts to modernize IT is the need to shift from all-in-one, monolithic systems to a modular IT architecture. In such an architecture, currently used or off-the-shelf software packages provide a backbone for functions with standardized requirements, such as billing and customer-relationship management. Companies should select software packages that meet their essential needs rather than opting for best-of-breed solutions. With a stable backbone in place, utilities can develop custom applications for functions such as product development or mobile-enabled field operations, where unique capabilities can provide competitive advantages.

• • •

Even in the most optimistic scenario, it takes years to transform a utility with digital technologies and methods—but we believe the ultimate outcome is worthwhile. Companies that make the changes described in this article can accelerate their digital transformations, and should stand a better chance of securing market share against digital attackers and transformed incumbents.

Read an extended version of this article on McKinsey.com: *Accelerating digital transformations: A playbook for utilities*.

Photo credit: Getty Images

Improving construction project performance: A conversation with Amit Varma

Has the construction industry been thinking about capital project delivery in the wrong way?

Amit Varma
Co-founder of VEERUM

Voices editors recently spoke with Amit Varma, a co-founder of VEERUM—a provider of industrial IoT technology—about how technology can inspire fundamental changes in the way the industry develops and delivers projects.

VOICES: *As technology solutions proliferate in the construction industry, what are the most important pain points that technology can help address? How do you expect these solutions to improve project performance—in terms of cost and schedule?*

Amit Varma: For the average industrial capital project team, things move so fast that what was true yesterday may not be true today. One significant pain point is that project teams currently don't have a window into a single source of truth. This is, at least in part, due to the fact that teams are so large. For a typical major project construction in Canada, there might be several thousand people, and a hundred vendors across multiple locations that form the project team.

Critical project information is often dispersed among dozens of contractors and hundreds of team members. Without the right information at your fingertips, chances are you won't find it fast enough to make effective project decisions. Compounding this is the fact that project activities happen in parallel; so when information is incorrect or simply misinterpreted, it contaminates the entire project. Mistrust is cultivated and project stakeholders waste time verifying data and information.

Technology platforms can help create this single source of truth. Cloud-based platforms are accessible and elastic in the sense that software applications can expand and contract as project teams expand and contract. The applications offer this flexibility while enabling geographically diverse teams to plan, execute, and monitor projects based on centralized data. Digital twin technology—which is used to create a virtual replica of a physical object or environment that can be used to simulate, operate, and analyze—contributes to the single source of truth by generating trustworthy, actionable information to base project decisions upon.

Another pain point for projects is that they are dynamic, complex systems, sometimes with a global footprint—and their moving parts, design, fabrication, and logistics must come together just in time for construction to be on cost and schedule. Technology can help solve this problem by bringing these moving parts together in a holistic approach. Rather than focusing on improving one part, solutions can offer connected insights throughout the design, fabrication, shipping, and construction lifecycle. It can identify mismatches that could cause construction rework, such as matching fabricated parts to design and virtually fitting them at the site. In this example, defects that could cause rework are detected before shipping parts. Defects can be corrected, or the site can be adjusted to accommodate them. Project teams can vastly improve cost and schedule performance by finding these potential mismatches and taking proactive steps to fix them before anything goes wrong.

The ability to evaluate data in real time, and make better decisions as a result, will likely spawn the biggest changes in how projects are developed and delivered in the future. While many technology providers serving the industry are working toward this vision, we are realistic about the current state of data management and don't expect the industry to become a utopia of freely accessible, shared data overnight. Rather than trying to solve the problem of fragmented data, we recommend that capital project owners focus on how to connect those fragments to bring more certainty.

VOICES: *What has to change to unlock the potential of digital solutions on construction projects—what are the biggest blocking points?*

AV: First, owners must start making strategic decisions about data upfront—what data will be collected to inform daily project decisions, who will access it, and how.

Once you're in the thick of a project, it's too late to think about what data you need. Construction projects contain massive amounts of data, but at the moment those data are trapped in systems that don't interact with each other, practically rendering them useless. In crafting their project plans, owners must incorporate digital strategies and prioritize interoperability so every byte of data collected at the day-to-day level is effectively applied to solve a problem.

Of course construction industry leaders are seeking answers to these problems. But they are often skeptical of digital solutions because they cannot quantify their value or return on investment. We believe there is value in risk mitigation for both owners and contractors. For example, you pay insurance on your house every year and hope that you don't use it; a digital twin platform for capital projects can similarly act like an insurance policy by helping preserve plans and managing risk.

Often, one decision maker may not have visibility of all the value as it extends beyond their scope of responsibility. So key decision makers should work to analyze and understand how a digital solution can provide benefits across the supply chain.

Furthermore, some owner companies are slow to develop the internal policies needed to safely adopt new technology on-site. Understanding the evolving regulations, particularly for on-site technology such as unmanned vehicles, also impacts the timeliness of adoption. Technology providers may find that they become key to providing input to the development of regulations. Regulation ideally will accommodate the unprecedented rate of change and be informed by facts, training, and experimentation.

On the broadest level, to unlock the potential of technology, industry leaders need to accept that the future is nothing like the past. The industry cannot seek to control change in a linear way, especially at the disruptive pace at which it happens. We should accept this is the new norm and seek out opportunities to experiment, learn, and adopt.

VOICES: *In an ideal world, how do you see the roles of the owner, contractor, and solutions provider evolving to mainstream digital solutions in the industry?*

AV: In an ideal world, the owner, contractor, and the solutions provider would work together and in each other's best interests so the project outcomes are achieved. Technology can enable this level of collaboration.

Artificial intelligence offers a chance to completely reimagine how we deliver projects. In the next few years, project teams will be able to make decisions guided by a system capable of calculating more optimization options than humanly possible. We need to keep our minds open to the fact we may have been thinking about capital project delivery the wrong way all along. It will be exciting to see how the industry evolves.

The roles of the owner, contractor, and solutions provider may evolve in terms of contractual frameworks. Each player has a wealth of data but they treat it as a proprietary competitive advantage in project bids. If owners and contractors combined their data to compute best outcomes, they would be much more effective together.

Imagine if a major project team was an orchestra, in which a large number of musicians in separate sections were playing a diverse range of instruments. Today, their song sheets are continuously changing between sections and out of sync with each other. Now imagine those musicians reading from the same song sheet, and the song sheet updating automatically based on changes in others' sections and tunes. The instruments are the finely-tuned digital solutions the industry so desperately needs; and the music created together would be a true piece of art that all the musicians would be benefit from, and broader audiences would be proud of.

VOICES: *What are the most exciting developments in engineering and construction digital solutions that we can expect to see unfolding over the next few years*?

AV: The most exciting developments are projects managed from start to finish with data that's centralized, interoperable, and practical for people to consume. For instance, a large Canadian energy player is monitoring earthworks at a construction site where, instead of traditional surveyors, a robotic drone and software calculates progress. Digital measurements lower costs and eliminate volume reconciliation issues. Earth movement is optimized by decreasing double handling. Removing people from working around moving heavy machinery reduces safety hazard.

Digitization will also impact schedules, as it did in the case of a global industrial fabricator where equipment sizing and orientation mismatches were digitally identified before the equipment left the fabrication facility. This prevented expensive and hazardous rework on site. The project was delivered two months ahead of schedule.

Enhanced environmental management is another exciting development. For example, we are in the early stages of working with a client who is building a 2,000 kilometre transmission line through a dense forest. A digital twin suggested the optimal path of the power line, minimizing the number of trees felled, while balancing cost and environmental regulations.

Of the many exciting developments in our field, the prospect of autonomous, safe, and sustainable construction of the world's infrastructure is the most exhilarating. We believe that this can be achieved in the near future and we are proud to play a part.

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.

Photo credit: Getty Images

Madrid 2018: A digital revolution in construction

Senior-level stakeholders in Spain gathered from across sectors to discuss construction's digital future. Read the key themes that emerged.

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McKinsey research shows that productivity in the construction sector has stagnated for decades. While this is driven by an array of reasons, the low degree of digitization in the industry is the largest differentiator between construction and the industries which significantly outperform it in productivity growth – including, but not limited to, retail, media, and manufacturing.

With so much to gain, the construction industry is poised for a productivity revolution and digitization may be one of the biggest drivers of change. Already, large amounts of capital have been invested in digital construction solutions and first-movers are adopting new technologies across the entire construction value chain. Digitally leading industries such as high tech, media, and telecom show that aggressive first-movers wield competitive advantages and fast-followers find it difficult to catch up.

In this peer-to-peer Global Infrastructure Initiative roundtable discussion, senior Spanish capital project and infrastructure leaders discussed the regional opportunities, challenges, and implications of the digital revolution in construction. The group represented a wide variety of sectors, including energy, real estate, engineering, construction, technology, and talent. Key insights included:

1. Integrate a tailored digital strategy focused on business value into your operating model. As a first step, the CEO, executive team, and board members need to develop a comprehensive strategy and transformation roadmap. This strategy needs to be based on a diagnostic that quantifies the impact of the digital strategy and the steps to realize its value. Importantly, it must be accepted as a tangible and pragmatic strategy by leadership.

2. Nominate a C-suite member to lead the transformation. The CEO or a member of the executive team should lead the transformation with clear communication of the strategy, roadmap, and objectives. This champion will need the full support of the board and executive team and a license to innovate, including retraining and recruiting personnel for new ways of doing things.

3. Introduce a culture of innovation. Tight margins and deadlines hinder attempts to foster a culture of innovation within organizations in the industry. However, leaders should be encouraged to create the opportunities and budgets for project leaders to experiment with new technologies. Similarly, creating a system for capturing lessons and refining best practices for re-use in other projects is essential for broader adoption. Crossrail's Innovation 18 program is a good example of how to create a culture of innovation.

4. Develop the necessary internal skills and capabilities to succeed. The construction industry traditionally falls behind when it comes to investments in R&D (1 percent vs. 3-5 percent in other industries) and IT (1 percent vs. 2-4 percent in other industries). This lag is also present in capability building with lower investment in training and upskilling. Increasing this investment, both through internal training and hiring new skills, is critical for better adoption and effective use of new digital tools. Moreover, processes and

mindsets will not evolve if staff members are not continuously prepared to implement new standards and don't see their leadership setting the example.

5. Involve stakeholders throughout the value chain. Changing an entire industry requires action along the full value chain. Digitization presents a tremendous opportunity for the industry to increase their competitiveness. However, siloed solutions have proven to fail in complex supply chains—and construction supply chains are among the most complex. Therefore, companies must define common standards, adopt ruthless transparency, and integrate their digital supply chain end-to-end to successfully and fully materialize the potential improvements from digitization. One idea to drive digitization and shape true digital projects is to form a network of partners that jointly invests in the future.

6. Learn from industries that are further along the road. Lessons can be learnt from industries ahead of the construction industry, such as aerospace and automotive manufacturing. In a closely adjacent sector, some international players in real estate have successfully adopted many digital tools including 5D BIM, control towers, augmented reality, robotics, 3D printing, and seamless collaboration platforms.

Photo credit: Getty Images

Frankfurt 2017: A digital revolution in construction

18 senior leaders from the German capital projects and infrastructure industry met to discuss the digital revolution in construction. Read the recap.

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Research from McKinsey Global Institute shows that productivity in the construction sector has stagnated for decades. While there is an array of reasons, the low degree of digitization in the industry is the largest differentiator between construction and the industries that have significantly outperformed it in terms of productivity growth since the start of the digital revolution, such as retail, media, and manufacturing.

However, the industry is in the midst of change, with large amounts of capital invested in digital construction solutions and first movers adopting new technologies across the entire construction value chain.

A peer-to-peer roundtable of 18 senior leaders from the German capital projects and infrastructure industry met during the inaugural Global Infrastructure Initiative roundtable in Germany to discuss the opportunities, challenges, and implications of the digital revolution in construction. The group of decision makers from a wide variety of industries, including energy, real estate, engineering, and academia fostered a lively discussion. The group discussed how today it is more important than ever for incumbents to stay ahead of the curve and move quickly and boldly.

During the roundtable participants saw first-hand how digitization in construction is already becoming a reality through the live demonstration of digital surveying and digital twin technology leveraging robotics and drones on a construction site thousands of kilometers away.

The subsequent panel and group discussions covered several themes and revealed these key insights:

1. The technology is available, but organizations need to increase adoption and pursue holistic digital transformations. The density and size of investments in technology startups in construction has grown significantly, and there are many solutions that provide the necessary technological backbone to drive holistic digital transformation of construction companies. However, players are slow to adopt them successfully. This is often driven by the hesitance of organizations to embrace the required transformation of mindsets and behaviors. For example, when running digital pilots, processes often remain unchanged, resulting in smaller than expected or even negative impact on performance. Only comprehensively revising existing processes will fully leverage digitization and create significant performance improvements. The idea of developing separate digital business units to run digitally-integrated construction projects and processes is viewed as a very attractive option to implement such holistic change.

2. Long-term winners in the German infrastructure market will invest in technology today, yet there is little urgency to change. The pipeline of capital projects in the German infrastructure market is huge and exceeds capacity of engineering, project management, and execution companies by far for the next decade. It creates a regional market that supports high prices and satisfying margins, but no pressure to differentiate. However, it is expected that the citizen pressure on public entities and the construction industry

to deliver more, better and cheaper infrastructure will grow significantly. Therefore, embracing digitization is not only a means to improve competitive positioning and increase profitability, but equally important to augment available capacity with existing resources in order to fulfill market demand. The regional industry can consider a change in business model – from purely monetizing the current opportunities to, instead, investing for a future where competition for market share will come from more digitized international players with better cost position.

3. Investment in capability building is critical to realize the full potential of digital tools. The construction industry traditionally falls behind other industries when it comes to investments in R&D (1% vs. 3-5% in other industries) and IT (1% vs. 2-4% in other industries). This lag is also present in capability building and lower investment in human capital. Many construction companies invest in as little as one day of training per year as opposed to approximately 15 days per year in other industries. Increasing this investment is particularly critical for better adoption and effective use of new digital tools in ways that realize their full cost savings potential, which McKinsey estimates can be up to 45 percent of project costs. Moreover, processes and mindsets will not evolve if staff is not continuously prepared to implement new standards.

4. Changing an entire industry requires change along the full value chain. Digitization presents a tremendous opportunity for private industry to increase their competitiveness. However, siloed solutions have proven to fail in complex supply chains—and construction supply chains are among the most complex. Therefore, companies must define common standards, adopt ruthless transparency, and integrate their digital supply chain end-to-end to successfully and fully materialize the potential improvements from digitization. At this point, though, many players along the construction value chain struggle to identify the natural leader in setting the standards among owners, general contractors, and E&C companies. One idea to drive digitization and shape true “digital projects” is to form a “network of partners” that jointly invests in the future.

5. It is not only about cost reduction, but about increasing clock speed and capturing new sources of revenues. Often companies are focusing on cost reduction opportunities as the key source of value. However, there are several other metrics across project performance they should integrate into their evaluation of new technologies, such as shortened timelines. For example, the analysis of data collected across thousands of projects and millions of sensors will allow for E&C companies to solve problems in a fraction of the time it takes today and for owners to implement predictive maintenance programs during asset operations to save costs and maximize asset revenues.

Several of these topics will feature in targeted follow-up sessions, which we are excited to host in the future.

Videos

Our videos help connect you with the leading voices in infrastructure today. We look forward to future conversations on these and other issues.

What the construction industry needs to know about Industry 4.0

Tackling infrastructure's digital frontier

Printing the future:
Ma Yihe, WinSun 3-D Printing

Videos are available at globalinfrastructureinitiative.com/voices

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Global Infrastructure Initiative

Since 2012, McKinsey & Company's Global Infrastructure Initiative (GII) has convened many of the world's most senior leaders in infrastructure and capital projects to identify ways to improve the delivery of new infrastructure and to get more out of existing assets. Our approach has been to stimulate change by building a community of global leaders who can exchange ideas and find practical solutions to improve how we plan, finance, build, and operate infrastructure and large capital projects.

GII consists of a global summit, regional roundtables, innovation site visits, and a quarterly digital publication, Voices. The fifth GII Summit will take place in London on October 29-31, 2018, and will focus on major project delivery and digital transformation.

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