

**WITHOUT
LIMITS**

AECOM

THE FUTURE OF INFRASTRUCTURE

Expert opinions from around
the world on the challenges
and opportunities ahead

FUNDING AND FINANCING

Finding solutions in a resource-
constrained environment

FASTER, SMARTER, BETTER

New approaches to delivering
future infrastructure

SKILLS 2030

How to build the future workforce

RESILIENCE

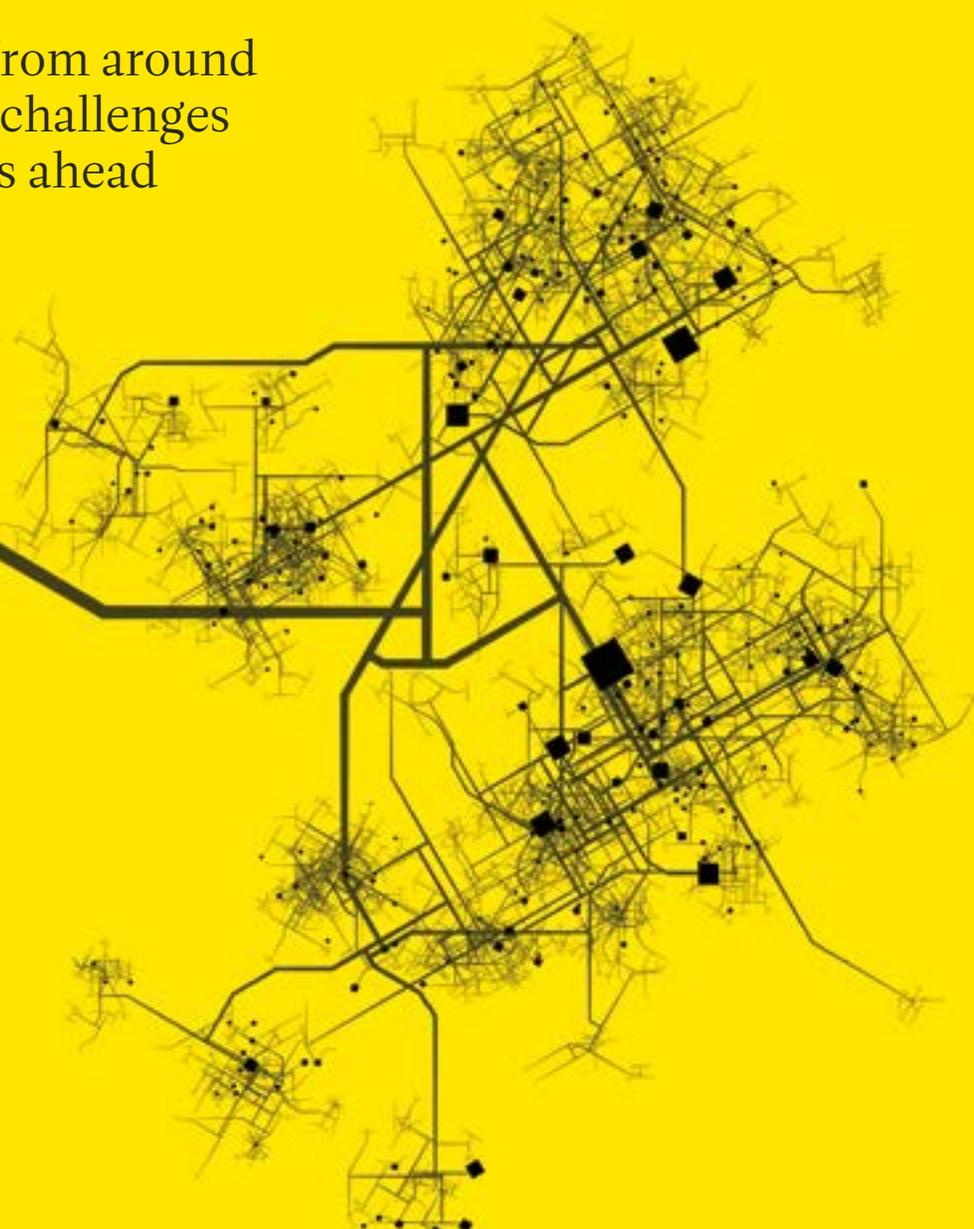
Future proofing and mitigating
physical and digital attacks

INNOVATION

Take a trip to a day in the life of 2030

2018

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THE FUTURE OF INFRASTRUCTURE

FOREWORD

Welcome to this first global research report from AECOM.

As a company focused on building a better world, we are passionate about our work in advancing infrastructure that improves quality of life and prepares us to meet the challenges ahead. Increasingly, we see networks and systems around the world coming under considerable strain. At the same time, as the physical and digital worlds converge, we are also witnessing amazing innovations and new ideas just around the corner. These are testing and exciting times.

As we speak with friends, colleagues and clients in the industry, we hear expressions of worry and optimism, caution and exuberance about what's ahead. To get an accurate picture of the times and how people think infrastructure may change in the future — or how the future may change infrastructure — AECOM has undertaken this research.

We surveyed more than 500 senior industry decision makers, all of whom work on infrastructure projects valued at more than US\$100 million, and we conducted detailed interviews with more than a dozen key figures in our industry. The aim has been to better understand the problems, priorities and potential in delivering major infrastructure projects.

We think that the findings are compelling. For example, nearly 70 percent of respondents feel that the industry is not evolving fast enough to meet our changing needs; one-third identify a lack of public funding as key to holding up new projects; and eight in 10 believe this is a pivotal time for civil infrastructure.



In addition to hearing from our survey respondents, we have included a number of articles in this report to address many of the key issues raised and to help inform new discussions that can unlock workable, sustainable solutions.

Amid the impacts posed by urbanization, climate change and the dizzying pace of technological advances, merely narrowing the infrastructure gap can no longer be a baseline goal for our industry, our clients and governments. What's needed is a giant leap forward — focusing the smartest minds, training and deploying more skilled workers, and leveraging new digital tools to deliver a better future through infrastructure.

Success lies in people working together with a shared vision in our industry and beyond. The potential offered by high-quality infrastructure is transformative, and getting it right is everyone's business. 

Michael S. Burke

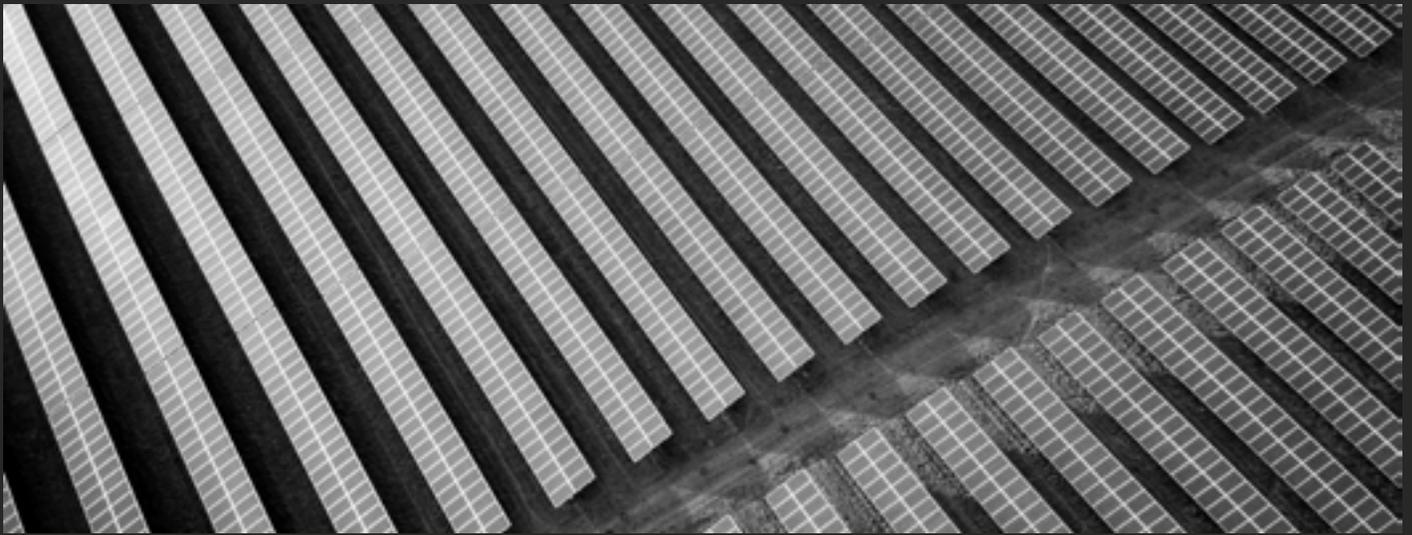
Chairman and Chief Executive Officer

Are you ready for the future of infrastructure?

Is your organization ready for the challenges and opportunities ahead?

Use our five-minute tool to find out how you compare with infrastructure organizations around the world.

Discover more
infrastructure.aecom.com/benchmarking



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A snapshot of key report highlights about the perceived value of infrastructure, the appetite for change, funding challenges and the desire for innovation to help make the big leap forward.

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Growth, Progress and Change: Why the Industry Needs to Speak Up

While there is broad agreement that infrastructure will play an important role in shaping our future, much has to change to meet growing demands for services.

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A Pivotal Moment for Infrastructure

Existing infrastructure is under strain as demand far outstrips supply. With future networks and systems slow to be delivered, it is time to embrace new tools and approaches, and develop a workforce for the future.

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With the increasing number of cyberattacks and extreme weather events, a focus on resilience is recognized as a route to supporting an improved quality of life for all.

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From the Jetsons to Futurama, and Star Trek to Blade Runner, we've all seen imagined futures. Veronica Siranosian and Andrew Bui look at some of the biggest emerging infrastructure trends.

INFRASTRUCTURE IS EVERYONE'S BUSINESS

Resilient and sustainable infrastructure is critical to economic growth and social progress. Looking at the challenges and opportunities ahead, the Future of Infrastructure report harnesses the views of more than 500 industry decision makers globally, all of whom work on projects of +US\$100 million.



GLOBAL 82%

NORTH AMERICA 83%



82% believe that investment in infrastructure is essential for national prosperity

FUNDING CLOSING THE INFRASTRUCTURE FUNDING GAP



INNOVATIVE MODELS
90% believe innovative funding models are effective at bridging the funding gap.



UNPREPARED FOR THE CHALLENGE
However, only 24% believe the industry is fully prepared for the challenge of attracting private investment.

RESILIENCE A COUNTDOWN TO CATASTROPHE?



CYBERATTACK OR CITYWIDE TRANSPORT DISRUPTION
71% say a major cyberattack or citywide transport disruption is probable in the near future.

ACCELERATED DELIVERY DELIVERING FASTER, SMARTER, BETTER



TRADITIONAL APPROACHES
71% believe traditional approaches do not fit the large, complex projects of the future.



SEAMLESS INTEGRATION
72% feel that digital integration is a long way from being a reality.

Changes in legislation and innovative funding models are needed to remove obstacles and allow the public sector to better access private sector financing.

Discover more:
THE INFRASTRUCTURE GAP: FINANCING AND FUNDING THE FUTURE, PAGE 20

Future proofing and protection to guard against cyber and physical attack are essential for all existing networks and systems.

Discover more:
RESILIENCE: IN A SHIFTING WORLD, PAGE 54

R E S P O N D I N G T O

As we enter the Fourth Industrial Revolution, the world of infrastructure project design and delivery is changing. Digital expertise is the key to a successful future.

Discover more:
DELIVERING FUTURE INFRASTRUCTURE: FASTER, SMARTER AND BETTER, PAGE 60



Investment is crucial to industry.

16%

Only 16% believe that the infrastructure industry is evolving fast enough to meet society's changing needs.

DELIVERY



TRADITIONAL APPROACHES
 Believe that many of the old, tried-and-tested approaches to project management are not meeting the demands of today's complex programs.

SECTORS INTEGRATION
 Believe that most projects are a long way from achieving seamless integration of providers.

SKILLS

INNOVATORS WANTED



21% **SOURCING THE RIGHT SKILLS**
 21% feel the industry is fully prepared to source the right skills to meet future industry challenges.



INNOVATION

THE INFRASTRUCTURE INNOVATION DEFICIT



3 IN 4 **OUT OF SYNC**
 Three-quarters believe that alternative technical concepts from the private sector provide the best opportunity to develop innovative infrastructure solutions.



THE CHALLENGES

Industrial Revolution, we need to rethink our approach. Connected seamless approach.

For the workforce of the future, the industry needs an image update — as a place that is diverse and inclusive, valuing wellbeing, innovation and career progression.

Innovation in projects and project delivery must go hand in hand with innovation in the workplace to guarantee future success in the industry.

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Executive Summary

AECOM's new research comes at a time of unprecedented complexity and transformation, complicated by rapid urbanization, demographic change and the maturing of our digital age.

Growth, progress and change: Why the industry needs to speak up

We find an industry that is unified in its belief that infrastructure will play an important role in shaping the society of the future. Over 80 percent of the more than 500 professionals surveyed agree that national prosperity depends on civil infrastructure.

Respondents also recognize the harm that will be caused if the industry cannot deliver on its promises. Congested roads, unreliable and overcrowded rail services, power outages, drought, flooding, and cyberattacks cost individuals, communities and industries billions of dollars every year.

To encourage greater investment, the infrastructure industry needs to do more to promote the positive contribution that it makes to people's lives. While government funding remains constrained, it is clear that work, including innovative funding models, is necessary to aid the flow of private money into public projects. More than one-third of global survey respondents cite funding shortages as the number one constraint in getting new projects off the ground.

A pivotal moment for infrastructure

Eight in 10 of the survey respondents agree that this is a pivotal time for civil infrastructure.

The industry must play a vital economic and societal role in supporting technological progress and shaping the communities of tomorrow. Our respondents share a willingness to embrace challenges and to develop fresh approaches to longstanding problems — and this must be done sooner rather than later.

Poor project and program management is also a major concern. A large majority of respondents feel that many tried-and-tested approaches fail to meet the requirements of today's increasingly vast and complex civil infrastructure programs. A logical inference is that the industry needs to run major infrastructure projects very differently.

In addition to developing new ways of running projects, workforce skills are also clearly a concern. One-quarter of the survey respondents cite skills and talent shortages as obstacles to progress, and about one-fifth say that difficulties sourcing the right talent cause major delays.

80%

Over 80 percent of the more than 500 professionals surveyed agree that national prosperity depends on civil infrastructure.

Building the resilient future

It is easy to get excited about the future. When considering transportation, for example, we all like to imagine a world of autonomous cars, digital railways that anticipate and help improve reliability, and Hyperloop links to usher in a whole new way of traveling.

Digital technologies and the Fourth Industrial Revolution are providing many of the tools we use; however, in today's digital world, protection against cyberattacks is one of the most critical aspects of resilience. When asked about the likelihood of certain events in the next five years, survey respondents offer a sobering assessment. About one in three believes that catastrophic events — a major ransomware attack or city-wide transport disruption — are almost certain in the near future.

As a result, we need to upgrade existing networks and systems, as well as create new ones; embrace innovation in the ways we work and the infrastructure we rely on; and ensure that the infrastructure we create is resilient and future proofed to help withstand the shocks and stresses to come.

Change is coming fast. We must leap ahead to build a better world and make sure no one is left behind.

Key Findings

1/

Future infrastructure will continue to play an important economic role, but is undervalued outside the industry



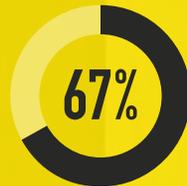
More than four-fifths of respondents say that adequate investment in infrastructure projects is crucial to national prosperity.



But they sense that this feeling isn't reciprocated on a wider level. Almost eight in 10 believe the sector's positive economic and social contributions are undervalued.

2/

Industry professionals are highly engaged, but they are also frustrated



More than two-thirds feel that the industry is not evolving fast enough to meet society's changing needs.



Their responses reveal that two out of every five major projects run into difficulties, causing serious delays. And only a slim majority of professionals believe they are good at responding to change, streamlining activities and adopting innovative delivery models.

3/

Infrastructure funding shortages are hampering progress



Some 39 percent identify a lack of public funding as the key reason why civil infrastructure is failing to keep pace with society's needs.



In many cases, this is a result of poor allocation of taxpayers' money. Nearly one-quarter of survey participants cite poor infrastructure project choices at the national government level as the reason why many new projects never come to fruition.

4/

The industry is experiencing an innovation deficit



Seven in 10 industry professionals say that tried-and-tested approaches are out of sync with the complexities they face. They need new technologies: three-quarters say alternative technical concepts from private contractors provide a great opportunity for innovative solutions.

Innovation is seen as the third most important skill for the future of infrastructure, but it is also the least available within the professional workforce. The workforce must be upskilled.





Part One

Growth, Progress and Change: Why the Industry Needs to Speak Up

In brief

01/ More than eight in 10 industry professionals agree that national prosperity depends on civil infrastructure

02/ It is widely acknowledged that the industry is not moving fast enough to meet growing demands

03/ We all need to be more vocal about infrastructure's positive benefits

04/ There are funding challenges, but they can be overcome with innovative approaches and novel solutions

AECOM's new research comes at a time of unprecedented complexity and transformation, complicated by rapid urbanization, demographic change, and the maturing of our digital age.

In turn, we find an industry that is unified in its belief that infrastructure will play an important role in shaping the society of the future. More than eight in 10 of the over 500 professionals surveyed agree that national prosperity depends on civil infrastructure. Strong transport connections enable urban regeneration, new job creation, and the delivery of goods and services.

Respondents also recognize the harm that will be caused if the industry cannot deliver on its promises. Congested roads, unreliable and overcrowded rail services, power outages, drought, flooding and cyberattacks cost individuals, communities and industries billions of dollars every year. Each one of us has experienced the frustrations and inconvenience of inadequate infrastructure.

Slow progress

Respondents say they have faith in the ability of government departments to select the right projects for their

communities, but our findings suggest that the industry is not moving fast enough to meet requirements.

Often, this is because the importance of civil infrastructure is overlooked. A concern voiced by many respondents was that infrastructure is taken for granted by the general public. Nearly 80 percent feel that the industry's positive economic and social contributions go unnoticed.

In the U.K., infrastructure is one of the few examples where the proportion of public spending is lower than taxpayers perceive it to be (3% actual versus 5% perceived — according to a recent government poll).¹

It is little coincidence that, in many advanced economies, infrastructure investment takes a back seat to areas such as health and education. Poor public relations may be to blame. Greater media coverage has created a level of awareness and understanding around other public services that infrastructure sorely lacks.

“

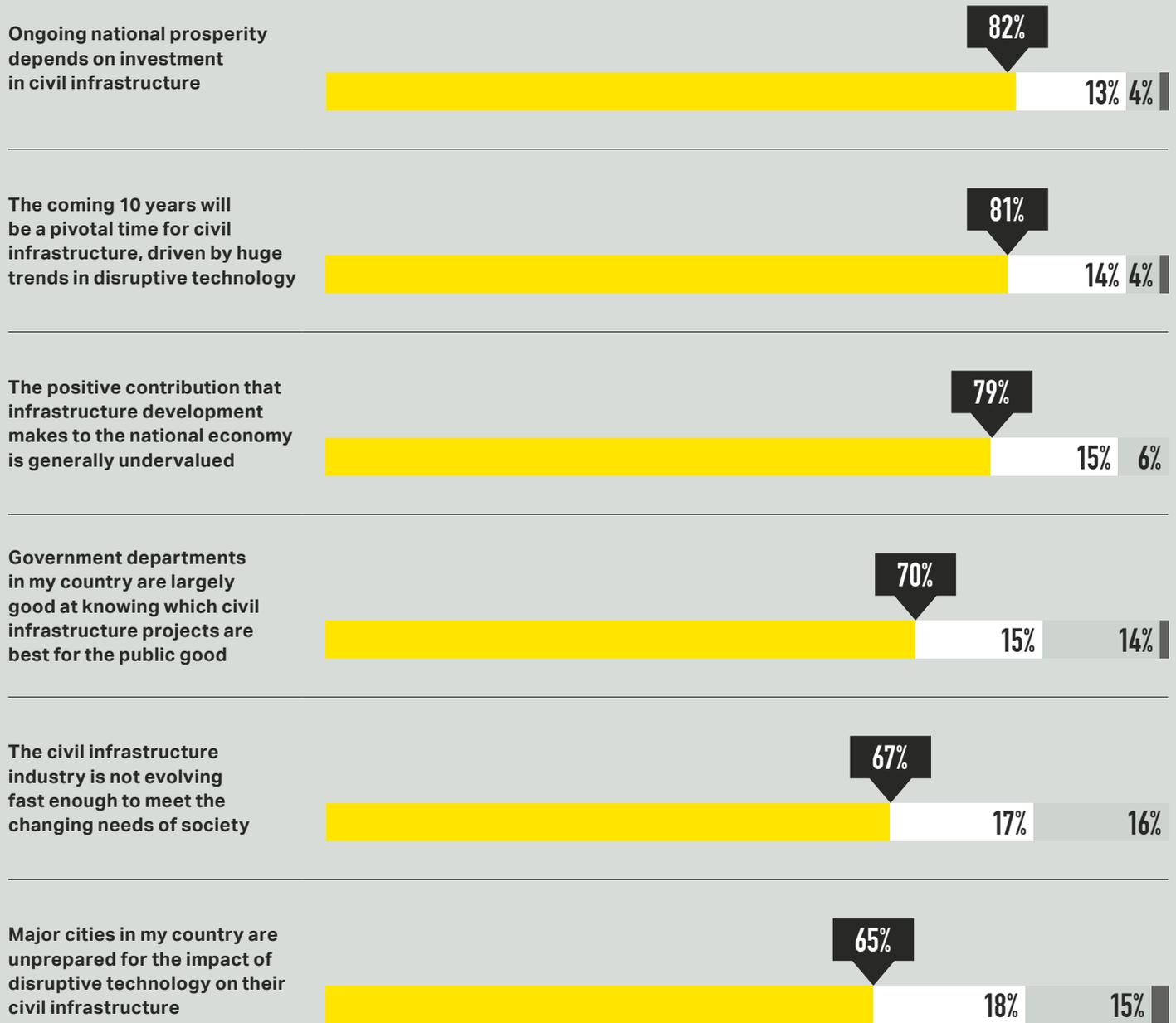
We've got one of the 10 fastest-growing populations in the OECD. Some of our capital cities will see growth of 40–50 percent over the next 15 or 20 years — there needs to be a very significant infrastructure response.”

— Philip Davies, Chief Executive Officer, Infrastructure Australia

¹ <https://yougov.co.uk/news/2014/11/09/public-attitudes-tax-distribution>

Figure 1/

Proportions of respondents that agree with key statements about the industry



Agree Neither agree nor disagree Disagree Don't know



There is a lack of understanding of how infrastructure is provided and maintained at a government level. People just think, “Why aren’t things changing?”

—
Therese McMillan, Chief Planning Officer, Los Angeles County Metropolitan Transportation Authority (LA Metro)

Government failure to provide clarity increases confusion around how major projects are selected and funded.

Infrastructure projects are largely publicly funded and owned, but can attract partnerships with the private sector that generate greater innovation, accountability, and long-term performance. The recent engagement of influential business figures — notably Elon Musk and Richard Branson — highlights the potential for attracting private enterprise.

The industry voice

AECOM’s strongly held view is that the infrastructure industry needs to become more vocal about the positive contribution that it makes to people’s lives.

When communities are properly consulted, informed and engaged in dialogue, they become powerful allies, enabling ambitious projects.

When Los Angeles County passed Measure M — an estimated US\$120 billion sales tax ballot measure designed to fund improvements to its highway and wider transportation network — over 71 percent of local residents voted in favor of the measure.²

Having the civil infrastructure debate openly — and on a human level — can elicit a sense of ownership among local communities and smooth the path to approving and financing new projects, as well as much-needed upgrades. Wider community engagement will also help to generate support for tariff-based payment models and other alternative funding solutions.

It is telling that many of the biggest success stories are occurring in isolation on a local or regional level. Despite plans to overhaul the United States’ infrastructure network at a federal level,³ performance across the country is inconsistent.

We also see a mixed picture when we look at the cities that are judged by our respondents to be performing well in the U.S. and the U.K.

In particular, the varied responses from U.S. participants in the survey highlight this disparity between the best-performing cities and regions and those lagging behind. Across all major areas of infrastructure, the same three cities — New York, Los Angeles and Washington, D.C. — are judged as being far ahead in terms of the progress they are making.

It is a similar picture in the U.K. Smaller regional cities, such as Sheffield and Leeds, lag behind the three largest urban centers of London, Birmingham and Manchester on transport, energy, water and resources.

Government-wide initiatives, such as the U.K.’s Construction 2025⁴ strategy, launched in 2013, are not translating evenly across the country.

² <http://theplan.metro.net>

³ https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/budget/fy2018/fact_sheets/2018%20budget%20fact%20sheet_infrastructure%20initiative.pdf

⁴ https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/210099/bis-13-955-construction-2025-industrial-strategy.pdf

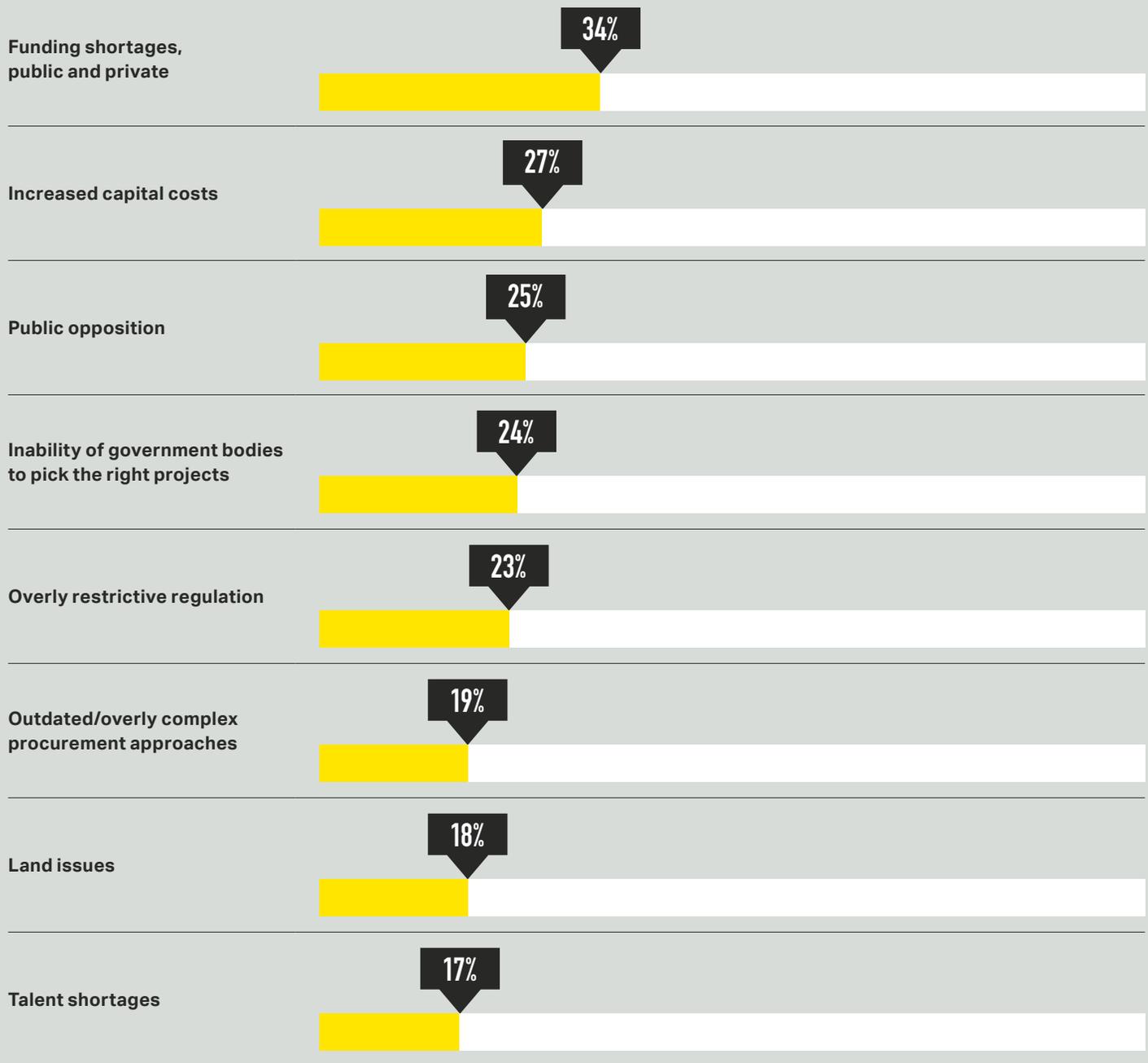
Figure 2/

How respondents rank major U.K. and U.S. cities on their progress in delivering future-ready infrastructure

	Transportation	Energy	Ports and waterways	Water resources	Wastewater	
						
U.S.	1	New York	New York	New York	New York	
	2	Los Angeles	Los Angeles	Los Angeles	Los Angeles	
	3	Washington, D.C.	Washington, D.C.	Washington, D.C.	Washington, D.C.	
	4	Chicago	Seattle	Miami	Chicago	Chicago
	5	Houston	Houston	Seattle	Miami	Seattle
	6	Seattle	Chicago	Chicago	Seattle	Miami
	7	Miami	Miami	Houston	Houston	Houston
U.K.	1	London	London	London	London	
	2	Birmingham	Manchester	Manchester	Manchester	Birmingham
	3	Manchester	Birmingham	Birmingham	Birmingham	Manchester
	4	Leeds	Glasgow	Glasgow	Leeds	Glasgow
	5	Glasgow	Leeds	Leeds	Glasgow	Leeds
	6	Sheffield	Sheffield	Sheffield	Sheffield	Sheffield

Figure 3/

Respondents who describe these issues as major reasons why projects fail to proceed



Agree



The performance of privately financed public infrastructure projects is compellingly better than traditional procurement. This can be brought about by the upfront process, which has the optimism of equity, the reality of debt stapled times three, competing over who can do the best thing for the best value for the customers.”

—
Brendan Lyon, Chief Executive, Infrastructure Partnerships Australia

Beyond the funding gap

In our research, inadequate funding is the largest perceived inhibitor of progress in the infrastructure industry. More than one-third of global survey respondents cite funding shortages as the number-one constraint in getting new projects off the ground.

Our respondents are not alone in having this viewpoint. According to McKinsey, 11 of the world’s 20 largest economies, including the U.S. and several leading E.U. member states, have reduced infrastructure spending as a proportion of GDP since the global financial crisis.⁵ The consultancy finds that the world needs to invest an average of US\$3.3 trillion annually to keep pace with projected growth through 2030. At the same time, the OECD says US\$71 trillion is required by 2050. And the G20 believes that US\$94 trillion is needed, and a US\$15 trillion gap needs to be bridged by 2037.⁶

**US\$3.3
TRILLION**

The world needs to invest an average of US\$3.3 trillion annually to keep pace with projected growth through 2030

Our view is that the funding gap is an issue that must be solved collectively at the federal and local levels by strengthening long-term funding sources for infrastructure, while sparing private-sector investment and state and local spending.

The survey identifies ways to meet the costs of building new infrastructure and maintaining existing assets. Among the more than 500 professionals consulted, a majority say innovative funding models are highly effective as a way to mitigate a shortfall. One popular solution, gaining recent momentum in the U.S., is to use public-private partnership (P3) models: approximately four-fifths of respondents select P3s as a way to improve traditional procurement.

P3-based models are not the only game in town. Many professionals would like to see user-based funding models built on enhanced approaches to traditional toll-gathering solutions (see Figure 4).

There may well be a place for new tariff-based solutions in cities — including advanced electronic toll collection and open-road tolling — whereby users can contribute directly to the cost of maintaining and improving essential transit infrastructure.⁷

It is critical to develop new channels to deliver funding to infrastructure projects. A significant proportion of survey participants also highlights the need for dedicated infrastructure funding that is protected within national budgets.

⁵ <http://www.un.org/pga/71/wp-content/uploads/sites/40/2017/06/bridging-global-infrastructure-gaps-full-report-june-2016.pdf>

⁶ <https://outlook.gihub.org>

⁷ <https://www.accenture.com/us-en/service-accenture-transit-tolling>



A GLOBAL PERSPECTIVE

Infrastructure funding:

While many countries face constraints on public funding, this snapshot of global opinion indicates substantial optimism around new funding solutions.

Mind the gap

A lack of infrastructure funding is a critical issue the world over, but it is especially acute in European economies.

In the U.K., only 35 percent of survey respondents say that civil infrastructure is well placed to contend with future public funding constraints, compared with 42 percent of professionals based in mainland Europe.

North America and Australia are more bullish. Nearly two-thirds of U.S. and Canadian respondents (62%), along with 58 percent of

Australian-based professionals, are optimistic about facing future funding challenges.

New approaches welcome — but not everywhere

Similarly, European professionals, as a whole, demonstrate deep skepticism about adopting new funding solutions.

Just 28 percent of the region's respondents see the use of public-private partnerships (P3s) as an effective option for bridging the infrastructure funding gap, while only 31 percent see the advantages of enhanced toll-gathering approaches.

There is greater enthusiasm elsewhere. Among North American respondents, 48 percent would like to see P3s trialed, and 45 percent support enhanced toll-gathering solutions. APAC professionals were 48 percent and 42 percent in favor, respectively.

For insight on infrastructure funding, see **The Infrastructure Gap: Financing and Funding the Future** on page 20

The way forward

A solution to the funding issue may be achievable, but the industry still faces many challenges as it looks to deliver the future infrastructure that society needs. In our research, respondents believe the industry is at a pivotal moment and that urgent action needs to be taken. They call for a fresh look at the process of infrastructure project delivery.

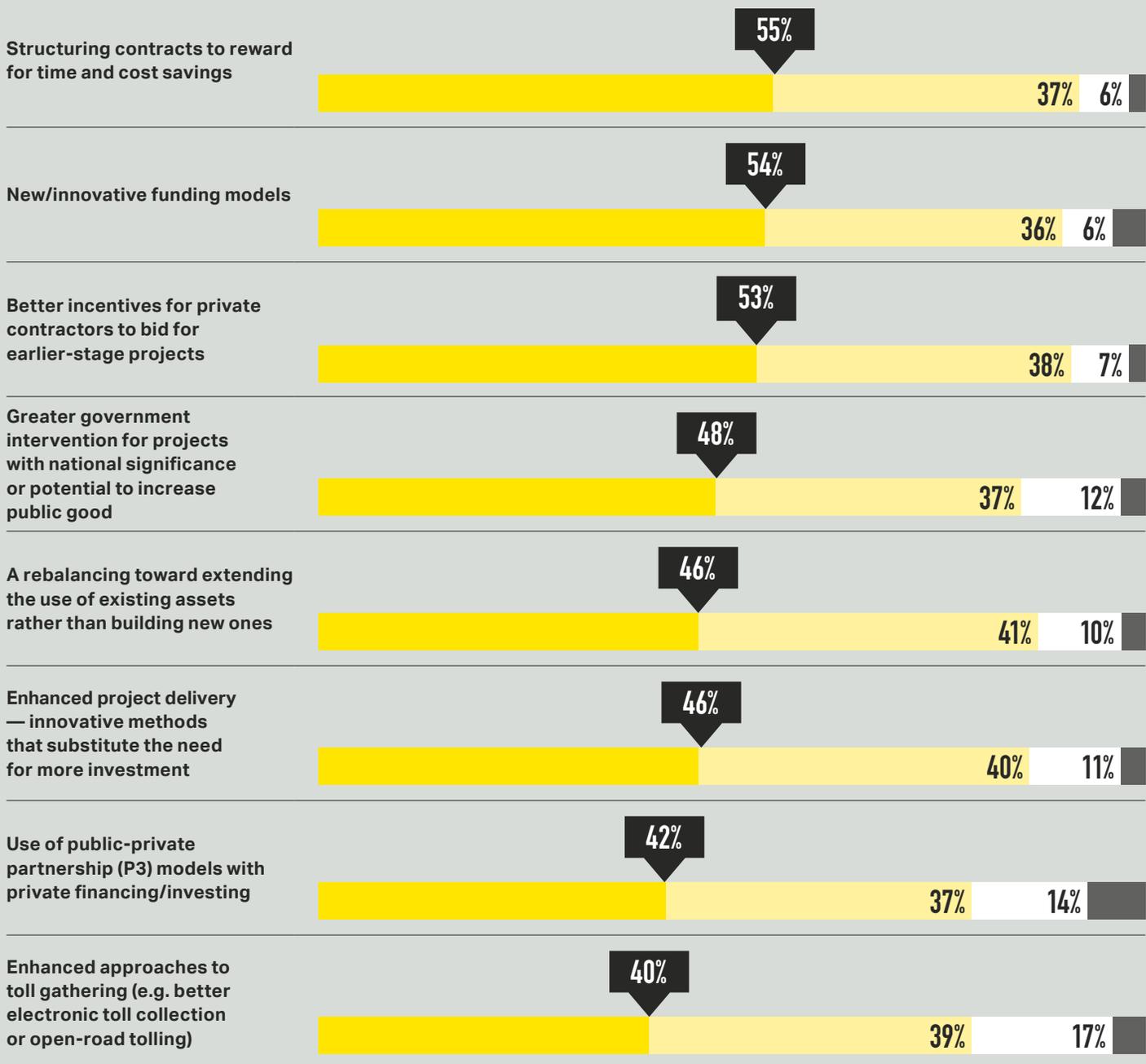
Significantly, respondents see increased support — from central government as well as local communities, businesses and environmental groups — as essential in keeping up with rapid demand for new projects. In the following sections, we explore these ideas in more detail and set out a new approach to resilience.

The consequences for all those involved in the funding, delivery and operation of infrastructure are far-reaching.



Figure 4/

Proportions of respondents that consider the following to be effective solutions to the infrastructure funding gap



■ Highly effective
 ■ Quite effective
 ■ Not at all effective
 ■ Don't know



A GLOBAL PERSPECTIVE

For insight on future infrastructure innovations, see **Stranger than Fiction: A Day in the Life of Future Infrastructure** on page 60

The value of infrastructure: As part of the challenge to attract more investment globally, the industry needs to promote the economic benefits of all categories of infrastructure.

Lack of recognition offers common ground
Worldwide, the lack of recognition for infrastructure's wider economic benefits is a common concern among industry professionals.

Eight in 10 respondents in the U.S., U.K. and mainland Europe agree strongly that their countries don't appreciate the economic value of infrastructure development to national prosperity, and this view is shared by 74 percent of APAC respondents.

A make-or-break time for all
The regions also agree that the industry faces a transformative decade. More than three-quarters of U.S., European and U.K. respondents say that technological change will make for a critical 10 years for the sector.

Nearly three-quarters (74%) of APAC respondents are in agreement.

An aerial night photograph of a complex highway interchange. The roads are illuminated with warm yellow lights, creating a glowing pattern of curves and straightaways. In the center of the interchange, there is a rectangular area that appears to be a soccer field, also illuminated. The surrounding area is dark, with some distant lights visible. The overall scene is a mix of infrastructure and sports, symbolizing the intersection of modern development and community amenities.

THE INFRASTRUCTURE GAP: FINANCING AND FUNDING THE FUTURE

With increasing urgency to resolve the financing and funding of infrastructure, **Michael S. Burke**, Chairman and Chief Executive Officer at AECOM, and co-author and Specialist Consultant, **Clive Lipshitz**, outline several approaches that, taken together, can help reduce the infrastructure gap.

In the following piece, we discuss ways to address the global infrastructure gap. The jumping-off point for our analysis is the observation from 39 percent of our Future of Infrastructure survey respondents that a lack of public funding is the key reason that civil infrastructure is failing to keep pace with society's demands. With massive infrastructure needs around the world, and against a reality of constrained public-sector budgets, bold leadership is needed to prioritize assertive public policy, harness private capital, and bring innovation to infrastructure funding and project delivery. While many of our observations and recommendations apply globally, much of the focus in this article pertains to the United States.

The infrastructure gap

The need for substantial investment in infrastructure has been well documented, with the McKinsey Global Institute estimating that US\$3.3 trillion must be spent annually through 2030¹ just to support expected global rates of growth. Most countries are not investing nearly enough, with an annual global shortfall of US\$350 billion.² The American Society of Civil Engineers (ASCE) estimates that if the 10-year U.S. infrastructure gap of US\$2 trillion is not addressed, it will cost US\$3.9 trillion in GDP by 2025.³ This shortfall affects everyday life — each year, two trillion gallons of drinking water are lost to water-main leaks,³ while 5.5 billion hours are lost to traffic congestion.⁴ Americans could soon experience “Thanksgiving-peak” transit volumes at 24 of the 30 largest airports at least once a week.³ Failure to invest in infrastructure is not just costly; it also impacts personal safety.

Almost 10 percent of the bridges over which Americans drive — about 56,000 in total — are structurally deficient, as are 15,500 dams (17% of the total).³ The infrastructure gap is exacerbated by factors such as climate and technological change.

How climate and technological change impact infrastructure

At the time of writing, Cape Town, South Africa, was just a few months from “day zero” when faucets will run dry and the city will have to adopt a network of water distribution points.⁵ It will take significant — and rapid — investment in desalination infrastructure to provide drinking water to the city's four million residents. Meanwhile, new technologies such as shared autonomous vehicles could wreak havoc on traffic assumptions that inform investment decisions.⁶ Anticipating such concerns, Los Angeles World Airports is reportedly incorporating within the design of what will become the world's largest consolidated rental car facility at LAX, the ability to support alternative uses if future rental car needs fall below current expectations.

Constraints on public-sector budgets

Public-sector budgets across the developed world are strained. U.S. state and municipal governments face unfunded pension liabilities of more than US\$1.6 trillion,⁷ diverting tax revenues away from infrastructure development and maintenance. Moreover, the U.S. municipal bond market, which has funded much public-sector infrastructure,



INFRASTRUCTURE INVESTMENTS ARE WELL SUITED TO THE PORTFOLIOS OF THE WORLD'S LARGEST AND MOST PATIENT POOLS OF INVESTMENT CAPITAL.

is facing headwinds as lower tax rates and persistently low interest rates make these bonds much less attractive to investors.⁸ It is noteworthy that municipal bonds are inefficient for tax-exempt investors, the largest pools of long-term capital, and they cannot be used to fund infrastructure developed by private-sector interests.⁹

Private capital is drawn to infrastructure, but with caveats

A relatively recent development in the financing of infrastructure is the significant and growing private-sector capital that has been drawn to these assets. Infrastructure investments are well suited to the portfolios of the world's largest and most patient pools of investment capital — the balance sheets of pension plans, life insurance companies, and sovereign wealth funds. Cash flows from infrastructure assets are reasonably predictable, of long duration, somewhat indexed to inflation, and relatively uncorrelated with public equity markets, all of which makes them a good match for the liabilities of life insurers and pension plans, and for the permanent capital of sovereign funds. For an indication of the possible magnitude of capital that could be directed to infrastructure investing, it is worth noting that U.S. public pension plans, corporate pension plans and life insurers hold assets of US\$4.2 trillion,¹⁰ US\$1.5 trillion,¹¹ and US\$6.8 trillion,¹² respectively, while sovereign funds globally hold assets of US\$7.4 trillion.¹³ Allocations of five percent of the portfolios of these asset pools to infrastructure would equate to close to US\$1 trillion, with upside from non-U.S. pension plans and insurers, and from higher allocations. →

¹ Equating to 3.8 percent of global GDP.

² Jonathan Woetzel, Nicklas Garemo, Jan Mischke, Martin Hjerpe, and Robert Palter, “Bridging Global Infrastructure Gaps,” McKinsey Global Institute, 2016.

³ Economic Development Research Group, “Failure to Act: Closing the Infrastructure Investment Gap For America's Economic Future,” American Society of Civil Engineers, 2016.

⁴ National Economic Council and President's Council of Economic Advisors, “An Economic Analysis of Transportation Infrastructure Investment,” The White House, 2014.

⁵ <https://www.timeslive.co.za/news/south-africa/2018-01-09-april-22-is-cape-towns-new-day-zero/>. Accessed on January 13, 2018.

⁶ The risks of technological change are well illustrated by the near-miss experienced by the Port Authority of New York and New Jersey which, in the 1950s, sought to take over and expand the many small piers in Manhattan. Fortunately, the authority was unsuccessful in its attempt to take on the piers as they were rendered obsolete by the introduction of containerization. The authority would go on to develop what at one point was the largest container port in the world in Newark/Elizabeth. See Jameson W. Doig, “Empire on the Hudson: Entrepreneurial Vision and Political Power at the Port of New York Authority,” Columbia University Press, New York, 2001, 374-375.

⁷ Jean-Pierre Aubry, Caroline V. Crawford, and Alicia H. Munnell, “State and Local Pension Plan Funding Sputters in FY 2016,” State and Local Pension Plans Number 56, Center for Retirement Research at Boston College, July 2017.

⁸ The volume of revenue bonds issued by U.S. municipalities peaked in 2006 and has been relatively flat since 2001. See <https://www.bondbuyer.com/broker/bond-buyer-data>.

⁹ Private sector developers can make use of private activity bonds, which are tax-exempt bonds issued by state or local governments for developments sponsored by private sector interests.

¹⁰ National Association of State Retirement Administrators, <http://www.nasra.org/>, data as of September 30, 2017. Accessed on January 8, 2018.

¹¹ This data is for the largest 100 pension plans. See Zorast Wadia and Charles Clark, “Milliman Analysis: Corporate Pension Funded Status Improved by US\$26 billion in September, Best Improvement of 2017,” Milliman, October 2017, data as of September 30, 2017.

¹² Statista, <https://www.statista.com/statistics/195086/us-life-insurance-total-asset-value-since-1989/>, data as of end of fiscal 2016. Accessed on January 8, 2018.

¹³ Sovereign Wealth Fund Institute, <https://www.swfinstitute.org/sovereign-wealth-fund-rankings/>, data as of December 2017. Accessed on January 8, 2018.

How institutional investors approach infrastructure investing

Most U.S. public pension plans invest in infrastructure through commingled funds managed by investment management firms. Many Canadian pension plans have adopted a more sophisticated approach of direct investments in infrastructure.¹⁴ CDPQ, manager of the Quebec Pension Plan, has even taken on development and operation of the Montreal light rail system.¹⁵ The largest sovereign wealth funds — which each hold assets of hundreds of billions of dollars — are attracted to infrastructure because of the scale it permits, since individual transactions can draw hundreds of millions in equity capital. Life insurers typically obtain exposure to infrastructure as lenders.¹⁶

Investment management firms helped catalyze the infrastructure allocations of institutional investors and have responded to the growth in such allocations with more and ever-larger funds. At the end of the first quarter of 2017, total assets under management by private infrastructure funds were US\$426 billion.¹⁷ This will likely increase substantially, driven by both supply and demand factors. On the supply side, several US\$10 billion-plus funds have been raised or are presently being marketed, while on the demand side, 53 percent of institutional investors surveyed plan to increase their allocations to the asset class.¹⁸

“
WHILE THERE IS STRONG INTEREST AMONG INVESTORS IN CASH-FLOW-GENERATING OPERATING ASSETS, PRIVATE CAPITAL IS VERY CAUTIOUS ABOUT INVESTING IN ASSETS WITHOUT IN-PLACE REVENUES AND IN GREENFIELD ASSETS.



MOST U.S. PUBLIC PENSION PLANS INVEST IN INFRASTRUCTURE THROUGH COMMINGLED FUNDS MANAGED BY INVESTMENT MANAGEMENT FIRMS.

Infrastructure investing strategies

Infrastructure investing strategies defy easy categorization. Many of the largest funds are finite-life vehicles that utilize private equity strategies and target high investment multiples rather than investment income as a source of returns, an approach known as value-add investing. At the other end of the spectrum, core funds hold assets for long periods and generate returns primarily from current income.¹⁹ Investment managers generally focus on brownfield operating assets, relatively few take on greenfield development risk, unless the development cycle is short and revenues are pre-contracted. Only eight percent of infrastructure funds take on opportunistic risk.²⁰ Funds may specialize by geography and/or asset type — for example, transportation, water, or energy assets. Distinct from funds that invest in the equity of infrastructure assets is a burgeoning category of funds that invest in infrastructure debt (10% of capital raised since 2008), although the vast majority of debt financing for infrastructure investments is provided directly from the balance sheets of banks and insurance companies.

Is this growing pool of private capital effectively addressing the financing needs for global infrastructure? We believe that the answer to this question is, at best, equivocal. In an industry-wide survey, investment managers' primary concerns were found to be transaction valuations (expressed by 53% of those surveyed) and deal flow (32%).¹⁸ Exacerbating these concerns is the growing accumulation of capital committed to funds but not yet invested (dry powder), which has grown to US\$151 billion²¹ and can be expected to increase as the trend of mega funds continues.²²

Why this disconnect between capital and investment opportunities? While there is strong interest among investors in cash-flow-generating operating assets, private capital is very cautious about investing in assets without in-place revenues and in greenfield assets.²³

There are no silver bullet solutions. And, given the stakes, inaction is not



an option in addressing global need. What is required is a combination of approaches aligned behind a strong vision, transparency, innovation, a conducive regulatory and permitting environment, and willing partners — across borders, governments and industries — that can rise above complicating factors and build trust that leads to confidence in proceeding.

In this spirit, we now turn to four approaches that taken together can be helpful in reducing the infrastructure gap.

1/ PUBLIC-PRIVATE PARTNERSHIPS

Public-private partnerships (P3s) are an effective way of transferring life-cycle costs of infrastructure off public-sector budgets and simultaneously create investable assets for the w. We expect that the P3 market — which is quite evolved in countries such as the U.K., Australia, and Canada — will deepen in the U.S. as concession terms become standardized and as valuation transparency is enhanced from higher transaction volumes.²⁴

P3s have demonstrated their value in projects around the world. Private investment in infrastructure, in partnership with the public sector, can motivate accountability in the delivery of critical assets, stretch public dollars and help local, state and national governments deliver highways, bridges, ports, airports and other infrastructure faster and cheaper, and ensure that they are properly maintained.²⁵



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**MANY
 INFRASTRUCTURE
 ASSETS ARE TOO
 SMALL ON AN
 INDIVIDUAL BASIS
 TO ATTRACT THE
 ATTENTION OF
 INVESTORS.**

airlines. Similarly, the Tennessee Valley Authority — whose service area covers portions of seven states — has invested significantly in infrastructure (power generation and environmental systems), while also spurring regional economic development. We believe that these and similar bodies should remain a core component of national infrastructure policies.

Regional P3 centers

Governments seeking to advance P3s in a programmatic manner might adopt the successful model of infrastructure offices, such as the U.K.’s Infrastructure and Projects Authority and Canada’s Infrastructure Ontario and Partnerships BC. The role of these centers is, among other things, to spur P3 activity through encouraging enabling legislation, prioritizing projects, and interfacing between procurement agencies and private capital sources.

We recommend a regional approach to P3 centers for several reasons. A highly centralized model is not realistic in light of the federalized system of decision making in the U.S. At the same time, it is not realistic or efficient to replicate P3 centers in 50 states. Regional centers would standardize legislation and concession terms (in the absence of standardization, private capital would be disincentivized, from having to “reinvent the wheel” on each new transaction). Additionally, regional centers could act as advocates with all stakeholders — procurement agencies, legislatures, the public, and private capital. There is an important role for the federal government to support these centers. It could partially fund their budgets, deploy specialists (perhaps rotating out of private sector), and help with standardization of enabling legislation and concession agreements.³⁰ ➔

Delivering economies of scale through project bundling

Many infrastructure assets are too small on an individual basis to attract the attention of investors. A solution to this problem is asset bundling. For example, the Pennsylvania Rapid Bridge Replacement Project is a P3 that bundles 558 aging bridges.²⁶

2/ A REGIONAL APPROACH TO INFRASTRUCTURE

The realities of a federal system, the inefficiencies of completely devolving decision making and financing to the state and local level, and the reality that infrastructure is not artificially bounded by state lines (think port and airport systems, roads, rails, and waterways), all suggest that infrastructure could be tackled

on a regional basis. This is especially true as urbanization transforms many of our global cities into mega-regions, requiring broad and interconnected infrastructure systems. Today, 55 percent²⁷ of the world’s population lives in cities; that is projected to increase to 66 percent by 2050.²⁸

Regional infrastructure authorities

The U.S. has numerous authorities that operate — and have been responsible for developing — significant portions of the nation’s infrastructure. Among the advantages of these bodies is that they take a long-term and expansive view of infrastructure needs. For example, the Port Authority of New York and New Jersey used revenues from bridge and tunnel tolls to help fund development of nascent airports in the New York area.²⁹ Its scale allowed it to negotiate equitable terms with

¹⁴ The largest such plan, the Canada Pension Plan, has a US\$18 billion infrastructure portfolio. See 2017 Annual Report, CPP Investment Board. Converted to U.S. dollars at rate of C\$1.33 as of March 31, 2017 reporting date.

¹⁵ https://www.cdpqinfra.com/en/reseau_electrique_metropolitain.

¹⁶ Solvency II, which governs risk-management for European insurance companies, reduces the capital required to be held against infrastructure investments, making them more attractive to European insurers.

¹⁷ Prequin Real Assets Spotlight, November 2017.

¹⁸ 2017 Prequin Global Infrastructure Report, Prequin Ltd.

¹⁹ Many core funds are evergreen vehicles, which can hold investments indefinitely.

²⁰ Prequin quarterly reports, December 2017, data for period January 2008 through September 2017.

²¹ Prequin Fund Performance and Dry Powder, data as at June 2017.

²² <https://www.bloomberg.com/news/articles/2017-05-22/blackstone-jumps-on-plans-for-40-billion-infrastructure-fund>.

²³ One exception is in the case of energy assets — oil and gas energy infrastructure has long attracted speculative capital, while development of renewable energy assets is often done on the basis of pre-contracted revenues through power purchase agreements. Approximately 76 percent of all private sector greenfield infrastructure transactions (2009–2016) were in the energy (renewable and traditional) and utilities sectors (Prequin, 2017).

²⁴ Market failure in valuation is epitomized by the case of Chicago’s parking meter P3, which was valued by the city’s inspector general at US\$1 billion more than the city received from the concession partner. See <http://chicagoinspectorgeneral.org/publications-and-press/public-reports/igo-report-closely-examines-parking-meter-lease-recommends-major-reforms/>.

²⁵ P3s work, with some limitations, for social infrastructure, such as hospitals, prisons, schools, courthouses, and civic centers. P3s for these assets generally rely on availability payments.

²⁶ <http://parapidbridges.com/>. An essential facilitating factor for willingness of private sector interests to participate in bundled assets is the availability of credit ratings, see “Bundling: A Growing Trend As Stakeholders Look to Unlock The Potential of the Infrastructure Asset Class,” S&P Global Ratings, Jan 2017.

²⁷ Central Intelligence Agency, The World Factbook: <https://www.cia.gov/library/publications/the-world-factbook/geos/xx.html>.

²⁸ United Nations, Department of Economic and Social Affairs, Population Division, “World Urbanization Prospects: The 2014 Revision.”

²⁹ See Doig 2001.

³⁰ For further elaboration of this idea, see Carter B. Casady and R. Richard Geddes, “Private Participation in US Infrastructure: The Role of PPP Units,” American Enterprise Institute, 2016.

3/ BETTER MODELS FOR FUNDING OF INFRASTRUCTURE

Whether financed by public or private capital, there is much that can be done to enhance funding models for infrastructure assets.

Generate sustainable revenues through fair-usage charges

Many infrastructure assets, particularly in the transportation and water/waste sectors, are subsidized or free to users. This is not uniformly sustainable and so we recommend a reality where, in the words of the ASCE, users “pay... rates and fees that reflect the true cost of using, maintaining, and improving... infrastructure.”³¹ There are numerous examples where this reality has been recognized. New Jersey is considering a US\$0.90 surcharge on New York-bound trips to fund its portion of the Gateway rail tunnel expanding links between the two states.³² Israel — much of which is desert — has sustainable water resources, in part because water is priced at market rates to all users.³³ Airports — particularly in the U.S. — have argued for removal of caps on passenger facility charges, as these are a necessary source of funding for infrastructure improvements.³⁴ Of course, usage charges are not realistic for all assets, most notably in the case of rural transportation systems. In these cases, tax revenue will generally need to cover capital expenditures as well as operation and maintenance. That said, in the absence of market controls, these assets would need to be prioritized very carefully to avoid white elephant projects, such as the US\$400 million Ketchikan, Alaska “bridge to nowhere.”³⁵

Dynamic pricing and efficient use of infrastructure

Dynamic pricing is a usage charge policy that can both increase revenues and ensure efficient use of infrastructure assets. It could be applied to many infrastructure types — think highway tolls (reducing peak-hour congestion), passenger facility fees (charging more during peak travel times), and end-user water and electricity rates (reducing usage during periods of peak demand).

Creatively utilize value-capture techniques

Land and property values increase — sometimes dramatically — when they benefit from adjacent infrastructure. Value capture leverages the increase in real estate valuation to fund infrastructure development. One approach to value capture, used extensively to finance expansion of Hong Kong’s mass transit system is called “Rail plus Property.”³⁶ Hong Kong grants MTR, the private-sector transit operator, development rights above new stations. MTR uses its profits from newly developed real estate to fund expansion and maintenance of rail lines, allowing the city government to avoid taking on infrastructure development costs. The approach works because of Hong Kong’s extremely high density and land values and can be adopted by other densifying cities. More generally, transit systems can generate revenues from development of mixed-use real estate at transit nodes. Another approach to value capture is tax increment financing which finances new infrastructure from tax revenues that it generates. The extension of New York’s subway system to the Hudson Yards district was financed using debt that will be repaid with property tax revenues from to-be-developed real estate in the district.³⁷

Ensure dedicated and robust state and local sources of funding

A peculiarity of the U.S. federal system as it pertains to publicly owned infrastructure³⁸ is that it is not uncommon for the federal government to fund upfront capital expenditures, and for state and local governments to fund operation and maintenance.³⁹ Stressed state and local budgets inevitably lead to maintenance backlogs, which is why it is of prime importance that local sources of maintenance funding be developed from tax revenues and ring fenced, protecting them from being diverted to other budgetary needs.

Modernize the gas tax

The U.S. Highway Trust Fund, which finances most federal government spending for highways and mass transit, is funded primarily from gasoline taxes. The fund has effectively operated in deficit since 2008 because the tax per gallon of gasoline has not changed since 1993 and because it



LAND AND PROPERTY VALUES INCREASE — SOMETIMES DRAMATICALLY — WHEN THEY BENEFIT FROM ADJACENT INFRASTRUCTURE.



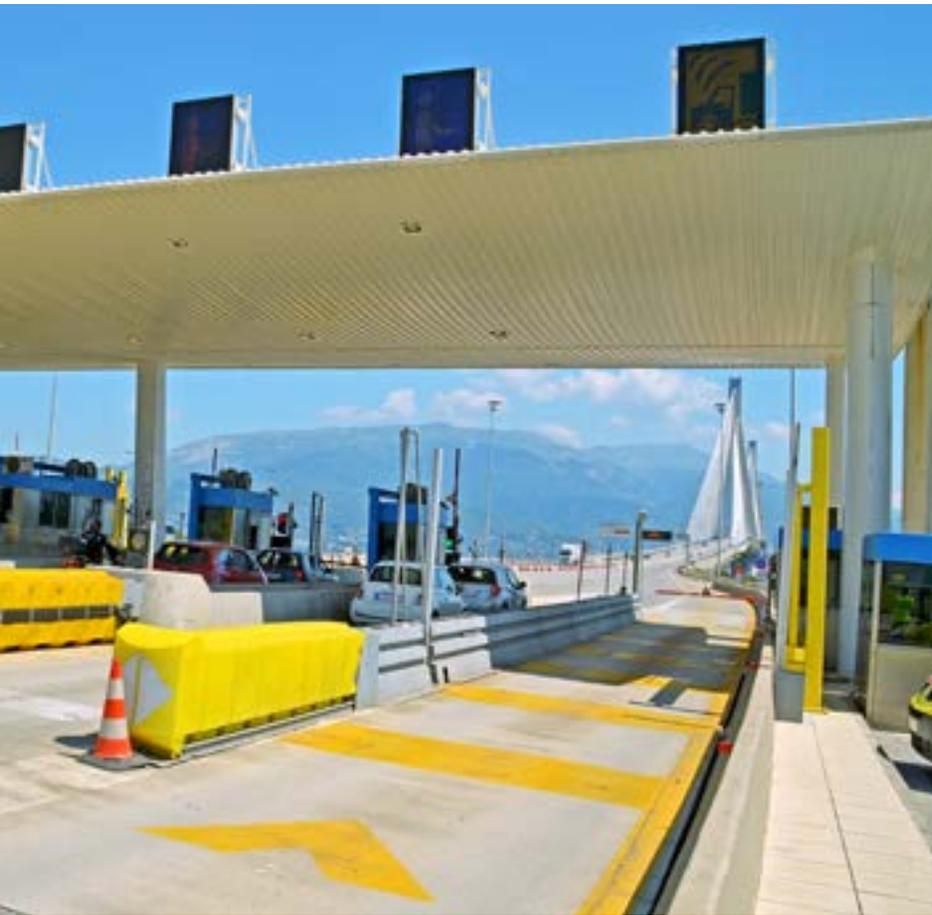
did not anticipate the significantly higher fuel efficiency of modern motor vehicles — not to mention the absence of revenues from electric vehicles.⁴⁰ Because wear and tear on roads is correlated much more closely to mileage driven than to gasoline usage, the fund could be stabilized using a mileage-based revenue source that accounts for both gasoline-powered and electric vehicles.

4/ ENCOURAGING GREENFIELD DEVELOPMENT

Development of new infrastructure requires substantial capital and entails significant risks. We propose several approaches to address these challenges.

Government-subsidized construction financing

As in many other countries, the U.S. has governmental programs that subsidize financing for infrastructure development. We believe that budgets for these programs should be expanded, as they are an effective way of providing leverage to federal funds, from private capital and state or local public capital, in the development and maintenance of infrastructure.



“
**AN EFFECTIVE
 WAY TO LEVERAGE
 PUBLIC CAPITAL
 IN A RESOURCE-
 CONSTRAINED
 ENVIRONMENT
 IS TO FUND NEW
 INFRASTRUCTURE
 VIA “ASSET
 RECYCLING.”**
 —

whereby the private-sector partner receives a flat fee and the public sector absorbs volume risk. Another consideration in new developments is political uncertainty — this is generally remediated by active stakeholder engagement⁴³ and by utilization of political risk insurance.

How AECOM reduces risks as a partner in greenfield development

The experience that comes from having managed Gantt charts on thousands of large-scale projects provides a firm like AECOM with deep institutional knowledge of how to create realistic budgets and project timelines. Moreover, from its experience migrating infrastructure assets to their ultimate owners, AECOM has garnered significant experience in the fine tuning of volume forecasts and operating expenses.

Reform regulatory and permitting practices

Predictable regulatory guidelines and efficient permitting processes can be helpful in driving private investment into infrastructure. In countries around the world, there are many cases of multi-year delays in project approvals because of inter-jurisdictional conflicts and changing environmental approval standards. Policies set by one administration or legislature can fall away with the next, creating uncertainty.

Conclusion

As we have argued, there are practical steps that can be taken right now by participants in the infrastructure market, as well as public policy initiatives that we actively support. In future articles we expect to expand our scope beyond the U.S. **WL**

TIFIA, WIFIA, and RRIF

The Transportation Infrastructure Finance and Innovation Act (TIFIA), the Water Infrastructure Finance and Innovation Act (WIFIA), and the Railroad Rehabilitation and Improvement Financing program (RRIF) provide loans and loan guarantees to finance development of new road, water, and rail infrastructure.

Asset recycling

An effective way to leverage public capital in a resource-constrained environment is to fund new infrastructure via “asset recycling,” whereby proceeds from the lease of existing assets are redeployed in the development of new infrastructure.⁴¹

Mitigate risks for private investors

Private capital is generally unwilling to invest in greenfield development because of the difficulties in accurately budgeting development costs and timelines, and forecasting future revenues in the absence of operating history. These concerns are heightened by well-publicized examples of projects going awry, such as Berlin Brandenburg Airport, which is expected to open almost a decade late and €4.5 billion over budget.⁴² These risks can be mitigated by inclusion of the right partner in the development and operating consortium. Private-sector investors will typically not take volume risk, which is why greenfield P3 concessions usually incorporate availability payment structures,

³¹ American Society of Civil Engineers, 2017 Report Card, <https://www.infrastructurereportcard.org/solutions/investment/>.

³² http://www.nj.com/traffic/index.ssf/2017/12/nj_transit_wants_to_hit_train_commuters_with_surcharge_raise_19b.html.

³³ Israel has invested heavily in desalination, water treatment, and a national water grid. For a comprehensive treatment of Israel’s water industry, see Seth M. Siegel, “Let there be Water: Israel’s Solution for a Water-Starved World,” Thomas Dunne Books, New York, 2015.

³⁴ https://www.aaae.org/AAAE/AAAEMemberResponsive/Press_Releases/2017/AirportsUnited_062217.aspx.

³⁵ <https://www.reuters.com/article/us-alaska-bridge/alaskas-bridge-to-nowhere-plan-finally-scrapped-idUSKCN0SI00120151024>.

³⁶ <http://www.mtr.com.hk/en/corporate/sustainability/2014rpt/finan-business.php>.

³⁷ For a description of the financing for this development, see Dan Doctoroff, “Greater than Ever: New York’s Big Comeback,” Public Affairs, New York, 2017, 161-162.

³⁸ In the U.S., approximately 90 percent of transportation and water/waste infrastructure is owned by the public sector, whereas more than 90 percent of power assets and 100 percent of telecommunications assets are owned by the private sector (McKinsey Global Institute, 2017).

³⁹ In the case of publicly-owned infrastructure, the federal government accounts for 38 percent of upfront capital expenditures; but only 12 percent of operation and maintenance expenditure. The rest is accounted for by state and local governments. See Debra Knopman, Martin Wachs, Benjamin M. Miller, Scott G. Davis, and Katherine Pfommer, “Not Everything is Broken: The Future of U.S. Transportation and Water Infrastructure Funding and Finance,” Rand Corporation, 2017.

⁴⁰ Pursuant to the Fixing America’s Surface Transportation (FAST) Act, Congress transfers general tax revenues to augment the Highway Trust Fund. A total of US\$71 billion was transferred in 2016. See Congressional Budget Office letter dated September 9, 2016 to Senator Jim Inhofe, Chairman of the Committee on Environment and Public Works: <https://www.cbo.gov/sites/default/files/114th-congress-2015-2016/costestimate/inhofeletteraugust2016hntf.pdf>.

⁴¹ Asset recycling has been used extensively in Australia where the federal government historically provided incentives (usually 15 percent) on top of lease proceeds.

⁴² <https://www.ft.com/content/b90c2a0c-e1b6-11e7-a8a4-0a1e63a52f9c>.

⁴³ For a comprehensive treatment of stakeholder engagement, particularly as it relates to infrastructure projects, see Witold J. Henisz, “Corporate Diplomacy: Building Reputations and Relationships with External Stakeholders,” Greenleaf Publishing Limited, Sheffield, UK, 2014.





Part Two

A Pivotal Moment for Infrastructure

In brief

01/ Rapid urbanization and population growth are putting existing networks and systems under strain as demand far outstrips supply

02/ Traditional ways of working are no longer fit for purpose and need to change

03/ Digitization is providing innovative tools and opening up new opportunities, particularly in transportation

04/ With new skills and approaches, the workforce of the future will be more diverse, increasingly collaborative and highly innovative

Eight in 10 of the industry professionals consulted by AECOM agree that this is a pivotal time for civil infrastructure. The industry needs to play a vital economic and societal role in supporting technological progress and shaping the communities of tomorrow.

Our respondents share a willingness to embrace challenges and develop fresh approaches to longstanding problems.

There is a clear desire for collaboration and knowledge sharing. This includes a desire to work with other stakeholders, to learn from the industry's successes and failures, and to take inspiration from elsewhere. But this must be done sooner rather than later.

Breaking point

Rapid urbanization and population growth are already putting increasing strain on the infrastructure of major cities — and beyond — and that strain is set to increase. In 1990, less than 15 percent of the global population lived in cities with populations of more than a million. According to forecasts by *The Economist*, that number is projected to rise to more than 27 percent by 2030. By then, nearly nine percent of the population will live in mega cities of 10 million or more.¹

The European Environment Agency (EEA) expects Europe's urban population to reach nearly 575 million in 2030, an increase from approximately 547 million in 2015.² North America's cities will experience similarly brisk growth, with the number of urban dwellers on the

continent growing from 300 million to 345 million during the same period.²

The problems aren't unique to the developed world. In China, for instance, 100 million rural workers are expected to move to cities between 2014 and 2020.³ How do we provide current and future infrastructure for this growing population?

New tools to deliver faster, smarter and better

The emergence of new technology will certainly help the industry respond to the demands of societal change. Recent years have seen some hugely exciting developments.

Transportation is being completely transformed by digital railways and autonomous vehicles. Hyperloop transportation systems — high-speed “pod” travel between cities — will follow.⁴ At the same time, beyond transportation, we have entered the era of the smart city. The pioneers of high-tech, intelligent urban environments, such as Chicago, Amsterdam and Singapore, are using emerging technologies — from data analytics to sensors and the internet of things (IoT) — to govern better, increase environmental sustainability, and improve the networks and systems that support the everyday lives of residents.^{5,6}

¹ <http://www.economist.com/node/21642053>

² <https://www.eea.europa.eu/data-and-maps/figures/urban-trends-by-world-regions>

³ [http://www.ey.com/publication/vwluassets/ey-publication-china-planning-for-an-urban-future/\\$file/ey-china-planning-for-an-urban-future.pdf](http://www.ey.com/publication/vwluassets/ey-publication-china-planning-for-an-urban-future/$file/ey-china-planning-for-an-urban-future.pdf)

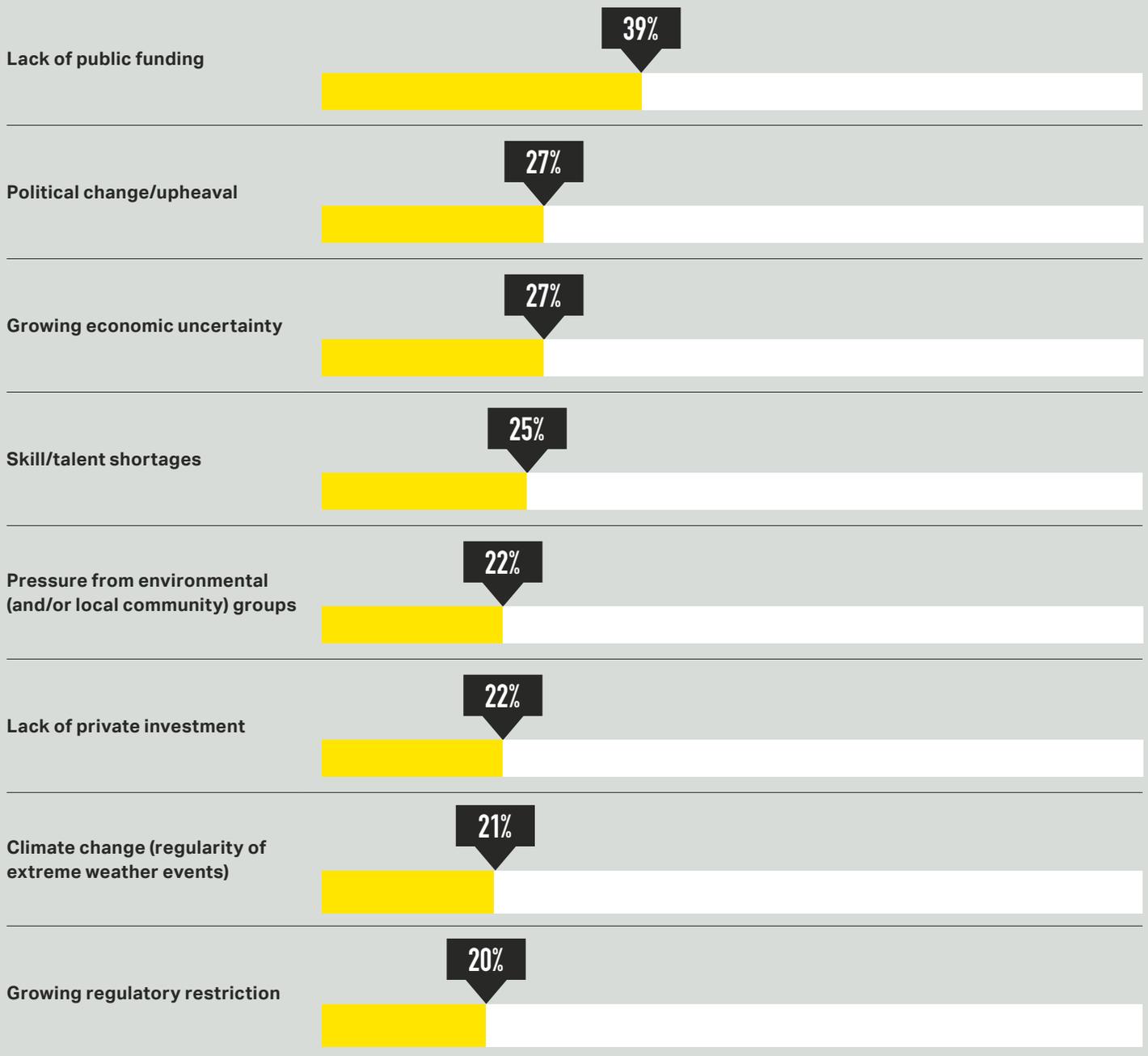
⁴ <https://www.designboom.com/technology/delft-hyperloop-pod-high-speed-travel-10-16-2017>

⁵ <https://sensus.com/internet-of-things/smart-cities/>

⁶ <http://www.ioti.com/smart-cities/why-chicago-smart-city-king>

Figure 5/

Respondents who think the following could significantly impact or restrict the industry's ability to deliver major civil infrastructure projects in the coming five years



 Agree



It's 16 years before High Speed 2 is fully open to Leeds and Manchester. That's a long time. If you go back 16 years, Apple had just launched the iPod. It seems a lifetime ago. So I think the issue for us is around thinking, 'Well, what would a railway look like in the 2030s?' We can't predict what's going to happen but we are giving this consideration into the way we design the railway system as a whole."

—
Mark Thurston, Chief Executive Officer, High Speed 2

And yet, to make the most of the new tools available, the industry needs to learn how to overcome some significant emerging challenges.

Managing external pressure

For many industry professionals, their ability to adapt to a changing society will be reduced by external factors. More than one-quarter of respondents to our survey see political upheaval or economic headwinds as potential stumbling blocks to progress in the next five years.

Meanwhile, respondents question the industry's resilience to a growing range of modern-day threats, including climate change and cyberterrorism.

Planning and delivery

Respondents to our survey reveal that even major civil infrastructure projects that come to fruition encounter problems, with four in 10 running into significant difficulties, causing major delays. They also indicate that approximately one-quarter of projects fail to get going until at least five years after the agreed start date.

Respondents suggest a variety of reasons for this inefficiency. Above all, they point to governance issues: late-delivering partners; unrealistic time frames; poor communication; and ineffective working relationships.

Today's rapidly growing infrastructure demands create a sense of urgency. Stakeholders are under pressure to deliver projects quickly — often at the expense of clarity and adequate planning.

Poor project and program management is also a major concern. A large majority of respondents feel that many tried-and-tested approaches fail to meet the requirements of today's increasingly vast and complex civil infrastructure programs.

A logical inference is that the industry needs to run major infrastructure projects very differently. The entire process should be reviewed — not just funding, but how projects are planned and delivered, how roles are allocated, and how different organizations work together.

An important part of any review of project delivery should be around communication. Nearly three-quarters of survey respondents say that most civil infrastructure projects are a long way from achieving seamless integration between providers. They single out competitive tendering, which is intended to get the best possible value for taxpayers but often imbalances the responsibilities and risks underwritten by different project partners.

Clear communication is also undermined by shielding information from rival bidders. A lack of dialogue means delays and complications. There are cultural drawbacks, too. Civil infrastructure companies engaged in bidding wars are discouraged from sharing best practices with their competitors. And innovations that give a competitive advantage are rarely brought out into the open.

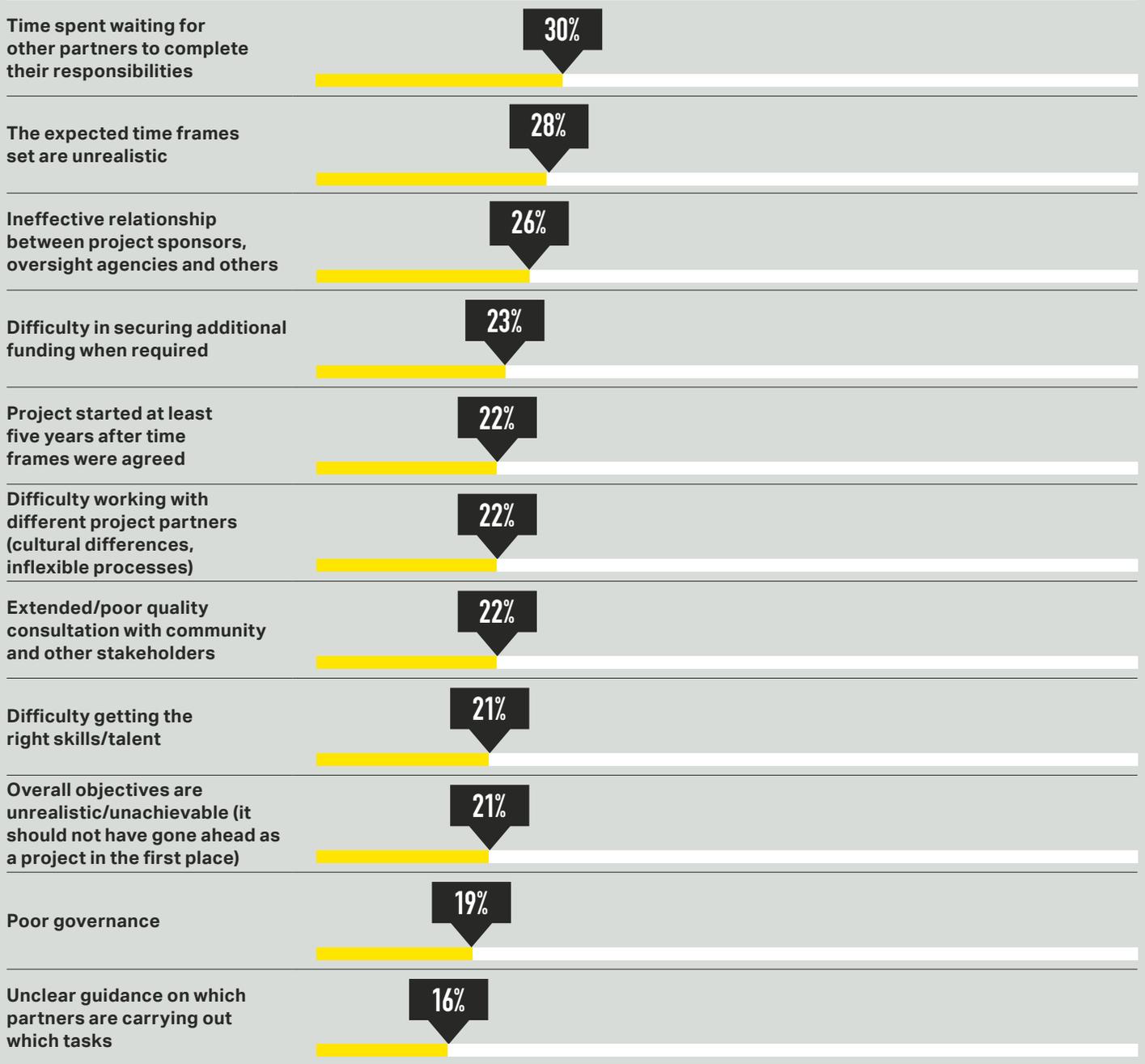


Voters want to see things moving at lightning speed. We need to build an understanding and manage expectations about how quickly and effectively we can implement change."

—
Therese McMillan, Chief Planning Officer, Los Angeles County Metropolitan Transportation Authority (LA Metro)

Figure 6/

Proportions that say these are the top reasons why major projects run over their expected time frames



■ Agree

Figure 7/

Respondents who rank their organizations as “good” at the following aspects of project delivery



Agree



“The construction workforce in Hong Kong is aging. We need employees who can work with new technologies such as BIM and who have knowledge of innovative construction materials and methods.”

— **Albert Cheng, Executive Director, Construction Industry Council, Hong Kong**

Industry professionals do, however, have some ideas about how to speed up project delivery with different approaches and technologies already in operation around the world. A combination of ideas and methods may be required, and the industry should seek inspiration from the successes and failures of recent years to find the best practice.

Key to better project delivery is the need to troubleshoot at the early stages of the project life cycle, where delays are most frequent and red tape can prevent new projects from getting off the ground.

Industry professionals also believe that stronger enabling legislation can help accelerate project delivery, while the same percentage call for earlier approval of environmental and other enabling works in the process (see Figure 9).

The broad range of solutions that respondents came up with underlines the reality. There is no single way to enhance project delivery.

The talent question

Any serious discussion on the future of infrastructure must address the talent question. In our view, civil infrastructure must take urgent steps to modernize, get better informed and arm itself with future-proofed skills.

One-quarter of the survey respondents cite skills and talent shortages as key obstacles to progress, and about one-fifth say that difficulties sourcing the right talent cause major delays (see Figures 5 and 6).

Employers display confidence in sourcing and retaining the core talents — engineering and project management. Attracting individuals to the profession who possess skills in technology and innovation is a far greater challenge.

72%

Nearly three-quarters of respondents to the survey say that most civil infrastructure projects are a long way from achieving seamless integration between providers.

It may be a question of image. As civil infrastructure struggles to integrate new technologies and practices, its reputation as an industry for top IT and computer science graduates suffers. That doesn't have to be the case — after all, the sector's challenges and opportunities are as inspiring, complex and demanding as those in any industry.



The logic was that you can only do so much to speed up the construction phase. Increasingly, we are seeing the value of trying different approaches. We've spent a lot of time reviewing environmental permitting processes, on planning processes and everything in between.”

— **Peter Rogoff, Chief Executive Officer, Sound Transit**

Figure 8/

Proportions of respondents that agree with the following statements about project delivery

A mix of private and public partners presents a range of different interests and priorities, which makes it harder for government to get maximum value



In a practical sense, most projects are a long way from achieving seamless integration of providers



Alternative technical concepts present the best opportunity for civil infrastructure projects to adopt innovative solutions from private contractors



Many of the traditional, tried-and-tested approaches to project management do not fit the demands of today's large, complex programs



 Agree



A GLOBAL PERSPECTIVE

For insight on delivery approaches, see **Delivering Future Infrastructure: Faster, Smarter and Better** on page 38

Infrastructure innovation:

With broad acknowledgment around the globe that tried-and-tested ways of working are no longer producing results, innovation is rising up the agenda.

No country for old approaches

Internationally, infrastructure professionals voice disillusionment with traditional industry approaches to project delivery.

Nearly three-quarters (74%) of European respondents believe that tried-and-tested approaches to project management are no longer meeting the demands of today's large and complex industry programs.

Some 72 percent of APAC-based professionals and 69 percent of those in North America share the same view.

New world, new ideas

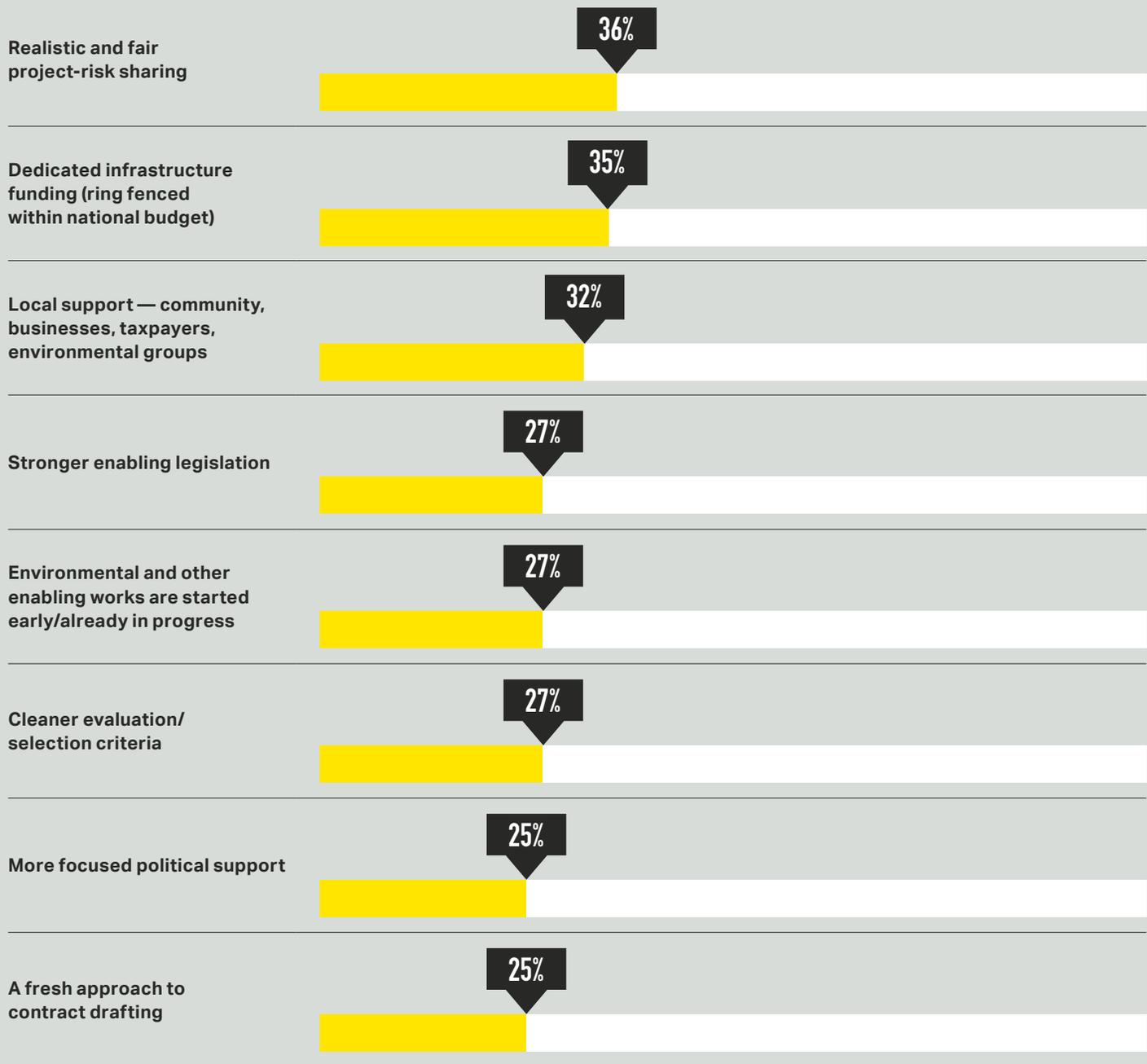
North America and APAC-based professionals show a strong appetite for adopting new industry approaches and techniques.

In both regions, around 80 percent of respondents believe that alternative technical concepts offer the best opportunity for civil infrastructure projects to adopt innovative solutions from private contractors.

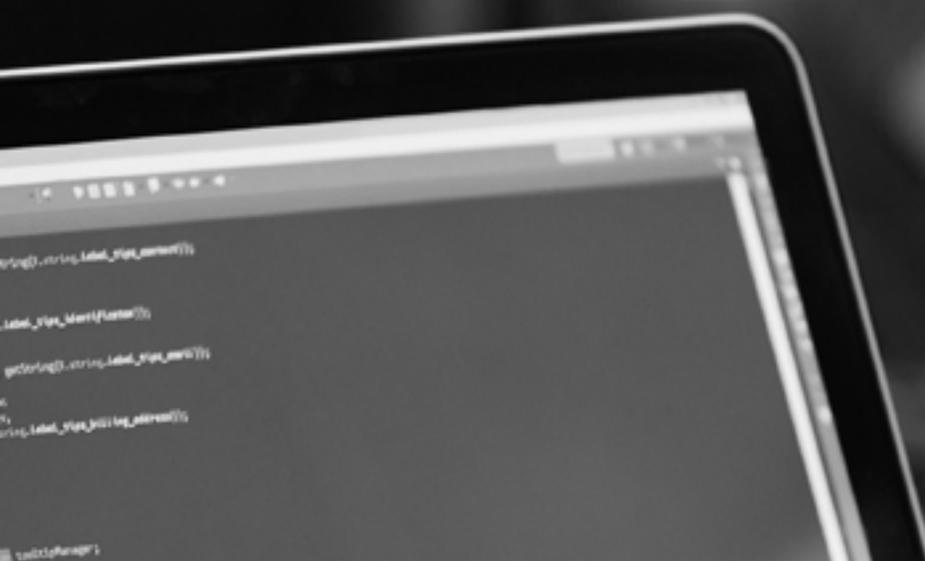
However, less than two-thirds (62%) of European industry professionals feel the same way.

Figure 9/

Respondents who think the following would make a noticeable difference to infrastructure project delivery



Agree



A GLOBAL PERSPECTIVE

For insight on training and securing the right talent, see **Skills 2030: Securing the Talent to Build our Future Infrastructure** on page 40.

Skills shortages and changes: While the ability to innovate is highly prized, different countries recognize that they are at varying stages of the re-skilling journey.

Innovators wanted worldwide
Workers with skills in innovation are in high demand around the globe.

Some 39 percent of North American industry professionals rank innovation among the top three skill requirements of the infrastructure industry in the next five years. In addition, 38 percent of APAC survey respondents and 33 percent of European participants are in agreement.

The brain drain continues
In each of the regions surveyed, the largest economy is winning the war for talent.

Skills that are designed to maximize innovation and new technologies are in especially short supply in the U.K. and Canada, where only around 45 percent of respondents feel comfortable with the infrastructure industry's current innovation skill level.

In contrast, German respondents place their industry's skill level at 80 percent in this area, while in the U.S. the figure is 66 percent.

DELIVERING FUTURE INFRASTRUCTURE: FASTER, SMARTER AND BETTER

As the industry seeks to bridge the global infrastructure gap, the delivery of many critical assets — essential to economic growth and the wellbeing of communities — is still being delayed. The combination of technology and alternative delivery can be truly powerful in solving this productivity issue, write industry-leading project delivery experts **Richard Robinson** and **Matt Forbes**.

Highway congestion, unreliable rail networks, power outages, water shortages and flooding ... infrastructure issues experienced daily and extensively around the world. And all this persists, despite the fact that we know bridging the global infrastructure gap is essential to economic growth and the wellbeing of communities.

However, a swift and effective response to these challenges is currently hampered by inefficient and outdated project delivery methods.

All too often, eagerly awaited and much-needed projects encounter massive delays to get off the ground, and then, once started, they run over time and budget. The 500 industry professionals surveyed in AECOM's Future of Infrastructure report say they have suffered significant yet avoidable delays on 40 percent of recent projects.

This is having a significant and measurable impact on economies. In the United States, a six-year delay in starting construction on public infrastructure programs manifests as a US\$3.7 trillion loss of output across the economy.¹ While in the United Kingdom, the cumulative impact of stalled projects during 2015–16 alone is projected to dent investment-related GDP to the tune of £35 billion (US\$46.7 billion).²

The productivity gap

The frequent failure to hit targets for cost, schedule and output have made infrastructure and construction notably poor performers in today's economic landscape. According to research by McKinsey, productivity in the U.S. construction sector has fallen by around 20 percent since the late 1980s, during which time it has risen by nearly 40 percent across the wider economy.³

The drag on productivity can be ascribed to numerous causes. The top concerns include a fragmented supply chain, with sub-optimal integration across different services; piecemeal procurement, with limited consideration of total cost of ownership or total life-cycle implications; resistance to change within the project cycle along with the effect of low margins on research and development investment; and limited adoption of new technology and best practices. For example, to this last point, according to the Future of Infrastructure report, only 56 percent of industry professionals rate themselves “good” at adopting and scaling innovative delivery models.

The result is a lose-lose for customers and the industry as a whole. Buyers get an inefficient, expensive service, often with delayed projects and poor-quality assets; suppliers struggle to survive financially.

And now for the good news

With numerous best-practice examples and exemplary projects, it is clear that the tools and approaches are available to produce a positive transformation in the delivery of major infrastructure projects. So, the challenge is to kick old habits and outdated ways of working and to build a new industry dynamic.

Our proposed two-step approach to solving the productivity issue embraces first, setting up projects differently to include a more integrated approach that links across the life cycle of an asset, reduces total cost of ownership and creates assets that are more constructible and fit for purpose. And second, deploying digital tools to unlock the full power of this integrated approach, which, in turn, sees the integrated approach release the full power of digital tools. We believe this approach could produce efficiencies of around 30 percent.



THE FREQUENT FAILURE TO HIT TARGETS FOR COST, SCHEDULE AND OUTPUT HAVE MADE INFRASTRUCTURE AND CONSTRUCTION NOTABLY POOR PERFORMERS IN TODAY'S ECONOMIC LANDSCAPE.

Exploring these items in more detail:

1/ SETTING UP PROJECTS FOR SUCCESS

The key here is to break down the familiar silo approach of plan, design, build, and operate and maintain. The following are some key ingredients for success:

- / Aligning all objectives and rewards across the supply chain to meet the client's key success factors.
- / A more honest dialogue around risk — with suppliers providing greater transparency on the true nature of risk in their own programs and owners willing to absorb more risk directly themselves.
- / Well-designed and performance-based partnership models that ensure all parties have “skin in the game” and are incentivized to deliver the best for the project and client (P3 being an extreme example of this, but other contract structures, such as design build or alliances, provide the opportunity to do this too).
- / Employers resisting the temptation of modifying existing well-defined contract structures, such as NEC in the U.K.
- / Using an organization specifically to act as “integrator” on major projects — managing the interface and relationships between different parties (including small and medium enterprises) across the life cycle — supported by the right technology platforms.
- / Getting the basics right: robust project setup; streamlined governance; and continuous stakeholder buy in.

2/ USING TECHNOLOGY TO UNLOCK THE POWER OF INTEGRATED DELIVERY

Digital tools can bring efficiencies in each individual service line, but they also enable the full power of an integrated approach, by providing the following:

- / A digital thread that ensures relevant asset data is passed between the phases of the project life cycle — a “running current” of consistent and appropriate

information to all stakeholders through the different stages of building and operating an asset. For example, how much more efficient could maintenance be if asset operators were handed an accurate and reliable picture of the asset they had inherited?

- / Enhanced and automated value engineering to create a more buildable and operable asset. For example, virtual reality (VR) solutions have the potential to merge separate delivery phases by offering an interactive and easily accessible digital design model. Stakeholders — whether owners, design specialists or ordinary users — can “walk through” the design of an asset in the virtual environment; approvals can be given, improvements identified and safety hazards avoided, minimizing setbacks and the need for re-work later on.
- / Digital engineering techniques, including automated design tools and the growing use of artificial intelligence (AI) and machine learning that not only replace repetitive manual tasks, but also use the power of machines to provide a more reliable outcome. These, in turn, enable new construction techniques such as the use of modular construction, 3D printing and increased use of robotics.
- / Asset intelligence (including the capture and analysis of performance data) to drive more efficient operations and feed back into future designs.

These tools maximize the efficiency of an asset over the whole project life cycle, resulting in lower total cost of ownership and enabling the full power of an integrated offer.

The future is within sight

While the industry has wrestled with its productivity challenge for many years, the time has come to embrace innovation and make the big leap forward. We now have the keys to unlock the future — and they lie in the combination of new delivery models and the smart use of technology. **ML**

¹ http://www.aecom.com/without-limits/wp-content/uploads/2017/10/performance-based-infrastructure_0.4_Ir.pdf

² <http://www.infrastructure-intelligence.com/article/oct-2016/infrastructure-delays-costing-uk-economy-over-%c2%a348000-minute-claims-new-report>

³ <https://www.mckinsey.com/industries/capital-projects-and-infrastructure/four-insights/the-infrastructure-conundrum-improving-productivity>

SKILLS 2030:

SECURING THE TALENT TO BUILD OUR FUTURE INFRASTRUCTURE

Technologies are transforming our lives and our world, impacting every type of infrastructure you can imagine. This shift requires new skills, such as greater creativity and innovation, better communication and collaboration, and more interdisciplinary specialists. Current debate within the industry is focused on how the role of the engineer must evolve in this new era. In response, **Roma Agrawal** and **Susan Dumond** propose a skills manifesto for creating the engineer of the future.

It's 2030. You're hiring. We're already looking at super-fast pod travel. Autonomous vehicles are the norm, and clean power generation has successfully seen the replacement of most fossil-fuel-driven power stations.

This vision of the future demands smarter, more sustainable and resilient infrastructure solutions as default, and you need a new generation of talent.

The challenges are familiar — they include training an interdisciplinary workforce, unleashing their imagination and expertise to solve future problems, anticipating which innovations and technologies will be in the ascendant, attracting greater diversity and inclusion, and working much harder to tell our extraordinary and inspiring stories.

Most pressing for the industry is the issue of how to train, attract, and retain the new kind of engineers needed to deliver our smarter networks and systems.

We are at the beginning of this journey. To help drive debate and action, we propose a Skills Manifesto to address infrastructure skills shortages and, more specifically,

create the engineer of 2030. What's the spark that will inspire the next generation? What, together, do we need to change? How do we create and encourage innovation?

We spoke to engineers, professional associations and academics around the world about their ideas, and how we might together design a route to the future.

Fire up the next generation

For the 2030 engineers, the future's bright. The future is exciting. In the coming years, these minds will reshape the world around us — radically transforming and improving the ways in which we live and work together, with the latest innovations and technology.

But the industry must work hard today, if it is to secure the talent that it needs for the future.

Around the world, countries including China, South Korea, Japan, the U.K., Germany, the U.S. and Brazil report an engineering skills gap.¹

Although widely respected, engineering still isn't seen as the most open, interesting or accessible career choice by young people.





Especially when it is compared to the more “exciting” options of medicine and law that they and their parents, teachers and career advisors see on TV every day.

In addition, we’re losing qualified engineers to other industries. In 2014, the U.S. Census Bureau reported that 74 percent of graduates with a STEM-related bachelor’s degree in the U.S. are not employed in STEM occupations.² While many of those that do work in these fields are choosing to benefit from the higher, more competitive salaries offered in the tech sector. Interviewed for AECOM’s Future of Infrastructure research, Peter Rogoff, Chief Executive Officer of Sound Transit, explains, “Here in Seattle ... the infrastructure sector struggles mightily to attract and retain good IT people. They can walk down the street and make a lot more money working for Amazon or Google or Microsoft.”

As an industry, the story we tell about ourselves needs to change — and fast. It needs to be human, impactful and, above all, authentic. Emanuela Tilley, Director of University College London’s (UCL) Integrated Engineering Programme (IEP), argues, “I think the students coming in have quite a higher level of empathy, and they want to make an impact on people’s lives ... we have to show the students how their work can really impact people.”

Brittany Harris, a graduate engineer currently featured in the Institution of Civil Engineers’ (ICE) Invisible Superheroes exhibition, agrees, “I chose to be a civil engineer because I wanted to make a positive change in the world ... but civil engineering is often misunderstood ... one way to attract a more diverse talent pool is to exhibit ... the contribution we make to society.”

Crucially, this story needs to be heard more widely. Peter McIntyre, Chief Executive Officer (CEO) of Engineers Australia (EA), sees this as a major priority for the industry in the future. “In Australia, we’re very good at talking to the profession about the smart things we do ... But we haven’t, traditionally, taken that discussion into the mainstream media ... anywhere near as well as we could ... I think that’s where we can start to change the hearts and minds of young students, parents and teachers.”

CALL TO ACTION

1/ Start talking:

We need to promote our industry and the opportunities it offers more broadly across society.

2/ Be human:

Ensure our story is as inspiring as our work, and the better world we can deliver.

3/ Be authentic, be impactful:

Tell the stories people can relate to, that show the benefits of future infrastructure to their lives.

Understand, confront and drive change

Our story matters. But so too do the people we have to tell it. The business benefits of diverse and inclusive teams are clear. As Deloitte’s latest Global Human Capital Trends report affirms, they are “more innovative, engaged and creative in their work.”³

But despite initiatives to increase diversity and inclusion within engineering, the global infrastructure sector’s workforce remains largely male, middle-aged and white.

We won’t change that reality overnight, but we can push harder and think more radically to achieve the progress we need much faster.

As Professor Dame Ann Dowling, President of the Royal Academy of Engineering, says, “It is time for a real culture change — the profession needs to be more inclusive. We have made real progress, but it is evident that the engineering workforce does not reflect the diversity of the overall working population.”

We need to start young, challenging the sexist and outdated assumptions — prevalent in the world around us — that still work to limit the ambitions of young people from more diverse backgrounds.

This ranges from the types of toys we give to our children to the leaders we develop and promote within our industry to be champions and advocates.

It requires us to draw on new faces and voices — people who haven’t necessarily been in the industry for decades but can speak with authority and authenticity, and engage those whom we’re currently failing to reach. ➔

¹ <http://qepriize.org/createthefuture/global-report-highlights-increasing-influence-engineering-economy/>

² <https://www.census.gov/newsroom/press-releases/2014/cb14-130.html>

³ <https://www2.deloitte.com/us/en/pages/human-capital/articles/introduction-human-capital-trends.html>

We need to be bold. Organizations across sectors are benefiting from breaking with traditional work practices and norms. This includes providing gender-blind application processes, reverse mentoring, tying reward packages to diversity results, and innovative flexible working initiatives.

We need to be brave, ensuring we rate people on more than their grades and subject choices. Professor Tim Ibell from the University of Cambridge asserts, “Engineers need to be good at STEM, of course, but of far greater importance is an engineer’s ability to be creative, deep thinking and able to work with others. To help achieve this, we need to place ‘Why?’ central to the education of engineers. The education of engineers has traditionally been focused on ‘How?’ and ‘What?’. When ‘Why?’ is added to the mix, the whole population becomes attracted.”

President of the American Society of Civil Engineers (ASCE), Kristina Swallow told us that greater community engagement and a focus on addressing our communities’ needs can also have an impact, “Doing this — becoming a more nimble, innovative, engaging profession — is one key to attracting a broader, diverse talent pool. Another, that is directly linked to the challenges we face, is to fully adopt sustainability design principles in all of our work. People from all walks of life can understand the opportunity and value in working on projects that improve communities as a whole.”

In addition, we need to be more honest with ourselves and each other. Research from the Royal Academy of Engineering found that, “White male engineers feel that the culture of engineering is more inclusive than female engineers, who in turn feel that it is more inclusive than engineers from black, Asian and minority ethnic (BAME) backgrounds.”⁴

Crucially, it highlighted the barrier of “inclusion privilege”, which means that “those who feel included are the least likely to take action.”⁴ If we want things to change, we can’t shy away from discussing these issues openly, together — revealing and addressing the unconscious biases that prevent fundamental change.

Dame Ann sees driving greater diversity and inclusion in engineering

as a fundamental part of her organization’s role in the future, “Together, we can challenge the status quo, sustain and extend networks, communicate and consult — both within and outside the profession — and continue to publish measures and benchmarks to track our progress.”

CALL TO ACTION

1/ Break with tradition:

If the way we’ve always done things isn’t delivering the results we need, then more radical change is essential.

2/ Talk honestly:

We need to uncover and address the unconscious biases and assumptions that currently go unspoken.

3/ Check your privilege:

Just because you don’t see a problem, it doesn’t mean a problem does not exist. We need to look again and think again.

Train for the unknown

On campuses across the world, there’s a revolution taking place in engineering education. Professor Mike Hounslow, Vice President and Head of the Faculty of Engineering at the University of Sheffield, explains, “We’ve undergone a period of significant change in the last 10 years; doubling the number of our students, investing in purpose-built facilities and continuing to improve their experience whilst studying here.”

The aim is to replicate the professional environment and practical challenges modern engineers will face in their careers every day, as closely as possible. For students at the University of Sheffield, UCL’s IEP and also institutions in Hong Kong, this includes giving students more opportunities to work in multidisciplinary teams tackling real-world problems.

An academic from a leading Hong Kong university states, “Innovative teaching and learning are important for training the next-generation engineers ... New teaching pedagogies involving structured active learning ... (experiential learning, blended learning and/or online learning) should be implemented ... in the years ahead ... We see the need of offering ‘multidisciplinary thinking’

“ IN CAMPUSES ACROSS THE WORLD, THERE’S A REVOLUTION TAKING PLACE IN ENGINEERING EDUCATION.”

in our engineering education — as emerging topics such as smart cities development will require engineers to work across different disciplines.”

As Emanuela Tilley, IEP Director at UCL, says, “It’s not solely about specific content anymore really or, indeed, traditional knowledge. It’s much more about processes and their [the students’] application of the knowledge.”

UCL also uses scenario-based learning, where students work on a discipline-specific, week-long project in small groups, such as designing a footbridge, tunnel or wind farm, instead of attending regular lectures. Emanuela Tilley is clear, “If you give a student a project, it has to be real.”

This commitment to authenticity must also extend to the environment in which they learn and the technologies they use. Professor Hounslow highlights, “In our main teaching building, The Diamond, we have a Siemens-sponsored facility for data visualization from a cloud-based platform and it’s connected live to real infrastructure, some of our own and some of our collaborators.”

Academic sources in Hong Kong and the People’s Republic of China (PRC) are united in citing initiatives incorporating new technologies, such as building information modeling (BIM), drones and other unmanned aerial vehicles (UAV), artificial intelligence (AI), smart solutions and 3D printing across research, and undergraduate and postgraduate teaching and learning in their institutions.

This focus, in large part in the PRC, is being driven by future infrastructure trends in smart cities.

At the University of Cambridge, they’re incorporating the pioneering work of the Cambridge Centre for Smart Infrastructure and Construction (CSIC) in the use of sensors in infrastructure across their engineering programs.

But Professor Tim Ibell, the Sir Kirby Laing Professor of Civil Engineering at the university, identifies a need for educators to go further, “The essential aspect will involve bravery in deciding which aspects of a traditional engineering degree should be dropped ... to embed more important skills which a 21st-century engineer will need. This will be controversial, but it must start now without delay.”

⁴ <https://www.raeng.org.uk/publications/reports/creating-cultures-where-all-engineers-thrive>

⁵ <https://www2.deloitte.com/us/en/pages/human-capital/articles/introduction-human-capital-trends.html>

⁶ <http://fortune.com/2015/07/23/humans-are-underrated/>

Our learning does not cease at graduation. Speaking at the 2017 IEEE Vision, Innovation and Challenges Summit, James Plummer, engineering professor and former dean at Stanford, stated, “The half of life of engineering knowledge is three to five years.”

More and more, our organizations will need to provide what Deloitte calls “always-on learning” — building cultures, platforms and spaces where people have the opportunity to develop, as well as potentially making learning a mandatory part of the work week. ⁵

ASCE President, Kristina Swallow is excited about the changes in teaching techniques and learning opportunities available to civil engineering students today, but recognizes there is still a lot to learn upon entering the field. “Throughout my career, I have seen that what I need to know now has changed ... with time, technology, and generally society, but it has also changed as my role has changed.”

Building on this, both new and more established members of the profession can learn a huge amount from each other, and valuable initiatives such as reverse mentoring can help make this a reality.

CALL TO ACTION

1/ Stay on the cutting edge:

Engineering teaching and learning must reflect the professional challenges, environments and tools of a modern engineer’s working life.

2/ Keep learning:

Inspire engineers to seek learning in their daily jobs.

3/ Maximize your existing workforce:

The knowledge and expertise of our people is one of the most valuable assets we have. We need to share this with each other.

Use what makes you human

Robots aren’t just coming to a desk near you. They’re already here. With more routine engineering tasks set to be automated, it poses the question, “What will humans do?” The answer, we’re pleased to say, isn’t as bleak as you might think. In fact, rather than being sidelined by machines, we’ll get to be even more of what we are ... human.

In “Humans Are Underrated”, Geoff Colvin asserts that our ability to empathize, communicate and collaborate with each other will be

vital to our future success, “We are social beings ... We want to work with other people in solving problems, tell them stories and hear stories from them, create new ideas with them.” ⁶

As we know, the future infrastructure engineer will need to be equipped and ready to lead and work in multidisciplinary teams, crossing specialisms, organizations, sectors and borders. UCL’s Emanuela Tilley is clear about the challenges this poses, “That is a very different way of working ... the language is different. The roles are going to be different, the understanding of how people work, timescales are going to be different.”

As academic staff in Hong Kong point out, “The top skills to acquire for students are innovative problem-solving skills that go beyond traditional knowledge or industrial ‘codes’. Students need to be more adaptive, innovative, research-minded, having the ability for self-learning and entrepreneurship.”

In the future, our organizations will also need to be as agile as the work we deliver, with teams being pulled together as projects demand. In response, our leadership and management practices will also become more fluid — evolving and changing with the development of each new project and team.

This creates exciting new opportunities for very different kinds of leaders and engineers to emerge: technical experts — yes, but also powerful communicators and, most importantly, committed listeners able to engage and secure the support of stakeholders to help solve complex infrastructure problems. ➔

CALL TO ACTION

1/ Embrace the future:

Technology will continue to replace some roles, but the very human skills of empathy, collaboration and communication will be at a premium.

2/ Break down silos:

Multidisciplinary teams will be the norm. We need to break out of our comfort zones to take on new ways of working to learn from each other.

3/ Listen and lead:

We need to empower our people to be ready to step up as leaders and managers, whenever the work demands.



Reboot the industry

It's always a gamble to predict what the workplace of the future might be. Nothing is certain, with new technologies, industries and roles emerging all the time.

But we do know some of the biggest, emerging trends set to reshape our working lives in the next 10 to 15 years.

First, we're already living and working longer than ever before. In "The 100-Year Life," Lynda Gratton and Andrew Scott propose that our traditional three-stage approach to life — education, career and retirement — is ripe for reinvention, with the majority of children in wealthy countries born today expected to live to be 100 or more.⁷

According to Gratton and Scott, future generations will experience multi-stage lives, and look to their employers to help them seize new roles and opportunities at different ages.⁷

As a result, our industry will need to offer more dynamic, less linear career models — creating new, flexible routes for individuals to build new skills that can lead them to different projects, functions and disciplines, supply chains and sectors; or even to become an entrepreneur inside a company.

Secondly, this demographic shift is making our workplaces more multi-generational, with Baby Boomers, Generation X and Millennials in the workforce together for the first time. "All of whom", PwC's Next Gen study states, "aspire to a new workplace paradigm that places higher priority on work/life balance and workplace flexibility."⁸

For some, this sounds like the death knell for the traditional "working day", with tech-empowered employees pushing to shift their hours and work to the times that best suit their own approach and lives.

It potentially also marks a transition to more community-based, shared workspaces that employees drop into and use as needed. As the PwC study shows, "They [Millennials] view work as a 'thing' and not a 'place'."⁸

This more fluid working environment will require a new kind of manager — someone able to lead and support a team of people, all potentially working in different ways, at different times, in different places, to ensure the client's needs are met.

Finally, as disciplines continue to converge, the future infrastructure industry will increasingly need to draw on the skills of engineers from other sectors.

Eugene Smethurst, Head of Process and Automation at AECOM, predicts, "A large-scale shift of technology engineers will move into this space from manufacturing, IT providers and CAD system providers, etc. ... they currently have the skill sets needed to transform future infrastructure, but are lacking in infrastructure knowledge."

This, in turn, demands we make it easier for different types of engineers to work in infrastructure.

CALL TO ACTION

1/ See the individual:

People will want to develop their careers in exciting new ways, throughout their lives. Find the strengths they bring.

2/ Construct new ways to work:

A shake up of the traditional "work week" is already here.

3/ Learn from others:

Innovations and skills from other sectors will help us to identify and deliver the next big things in the future of infrastructure.

Evolve to succeed

In this agile, smarter infrastructure world, we need our professional institutions to be more innovative, more vocal and more diverse drivers for change.

For ASCE President, Kristina Swallow, this means pushing the boundaries of what's possible in the industry, and promoting greater sustainability, "We need to continually support research and development of new, innovative solutions ... optimizing the assets we already have and developing projects that will be environmentally, economically and socially sustainable."

Discussing the ICE's work, graduate engineer Brittany Harris says the focus should be digital, "The future will require engineers to be more agile and forward thinking, taking into account the changing social, political and environmental climates. We have already seen a huge drive from the recent and current ICE presidents towards digital engineering, and I can only expect this to grow."



THE FUTURE INFRASTRUCTURE INDUSTRY WILL INCREASINGLY NEED TO DRAW ON THE SKILLS OF ENGINEERS FROM OTHER SECTORS.

The shift to digital highlights the growing need for professional organizations to widen their scope beyond their traditional disciplines to support their members and industry in an increasingly multidisciplinary future.

In addition, our professional bodies are crucial to promoting the positive economic and social impacts of smart infrastructure. Public debates about big issues like this are increasingly taking place on social media, where algorithms filter the content we see based on our existing views and likes. As a result, people's views are becoming more entrenched, whatever the facts.

Against this backdrop, Peter McIntyre, EA's CEO, believes one of his institution's most important roles in the future will be to try to break through this bubble, ensuring more rational, informed and honest debate about the big future infrastructure questions shaping people's worlds. "Without fear or favor ... we need to advocate for good public policy positions ... because we have the ability to talk ... from a position of political indifference and with a lack of partisanship ... based upon evidence and good critical thinking ... to try to guide the public debate."

Kristina Swallow agrees, "As experts in the field, it is important that civil engineers take on the roles of technical advisors and key influencers ... educating others about the importance of managing our existing assets, minimizing impacts to the natural environment and making sound infrastructure investments."

Our professional institutions also recognize a need to consult with their members more closely and amplify a range of voices across the sector. Peter McIntyre says, "We're now starting to design our processes to engage our members more deeply on issues ... I would like to envisage us as an organization that, using the power of social media, ... taps into the power of its own members to robustly develop and test its own positions ... that means you get greater ownership of those positions from members. It also means people feel they can actually contribute ... more fully."

⁷ <http://www.100yearlife.com/the-challenge/>

⁸ <https://www.pwc.com/gx/en/hr-management-services/publications/assets/pwc-nextgen.pdf>

For Professor Dame Ann Dowling, Royal Academy of Engineering President, the drive for change needs to start from within, “As an Academy, we have been on a journey towards ensuring that our staff and Fellows properly reflect the society we serve.

This began by addressing our own Fellowship and staff, and ... the Academy has just been listed as one of the top 50 inclusive employers in the U.K. We will continue to push for greater inclusion and diversity in the profession — it is vital for the profession’s health, and that of the U.K. as a whole.”

CALL TO ACTION

1/ Drive innovation:

As members, we can ensure that our professional associations embody and help us deliver the changes our industry needs.

2/ Break through the noise:

These organizations can leverage their members’ expertise to promote evidence-based debate and help change minds.

3/ Amplify our voice:

Together, these organizations can help us to develop increased ownership within our industry of the future we want to see.

WHO WILL THE 2030 ENGINEER BE?

No one can gaze into the future with 100 percent accuracy. Over the next decade or so, we’re going to continue to see new technologies disrupt the infrastructure sector in ways we can’t even imagine now, creating new kinds of industries and jobs as well as making others obsolete.

Based on our current research, we believe these are the top five skill areas that will set the 2030 engineer apart:

1/ NEW RULES. NEW ROUTES

It won’t just be an engineering degree that gets you through the door. The future infrastructure industry is going to be hungry for people qualified in IT, communications, art and design, and life sciences.

2/ ACROSS COMPANIES, SECTORS AND BORDERS

As infrastructure programs grow in complexity and geographical scope, the ability to collaborate and work effectively in multidisciplinary teams across different organizations will be invaluable.

3/ INNOVATING ACROSS THE PROJECT LIFE CYCLE

The future engineer will use present-day innovations such as BIM, AI and 3D printing as standard. They will be expected to identify and take advantage of the efficiencies that these and other innovative tools, such as sensors and robots, deliver.

4/ AND WHAT DO YOU DO HERE?

It’s increasingly likely that the jobs of the engineers of the future will fall into three main categories:

Generalists — technical experts, also equipped to provide in-depth knowledge of clients’ key infrastructure challenges, from finance to regulation and program management.

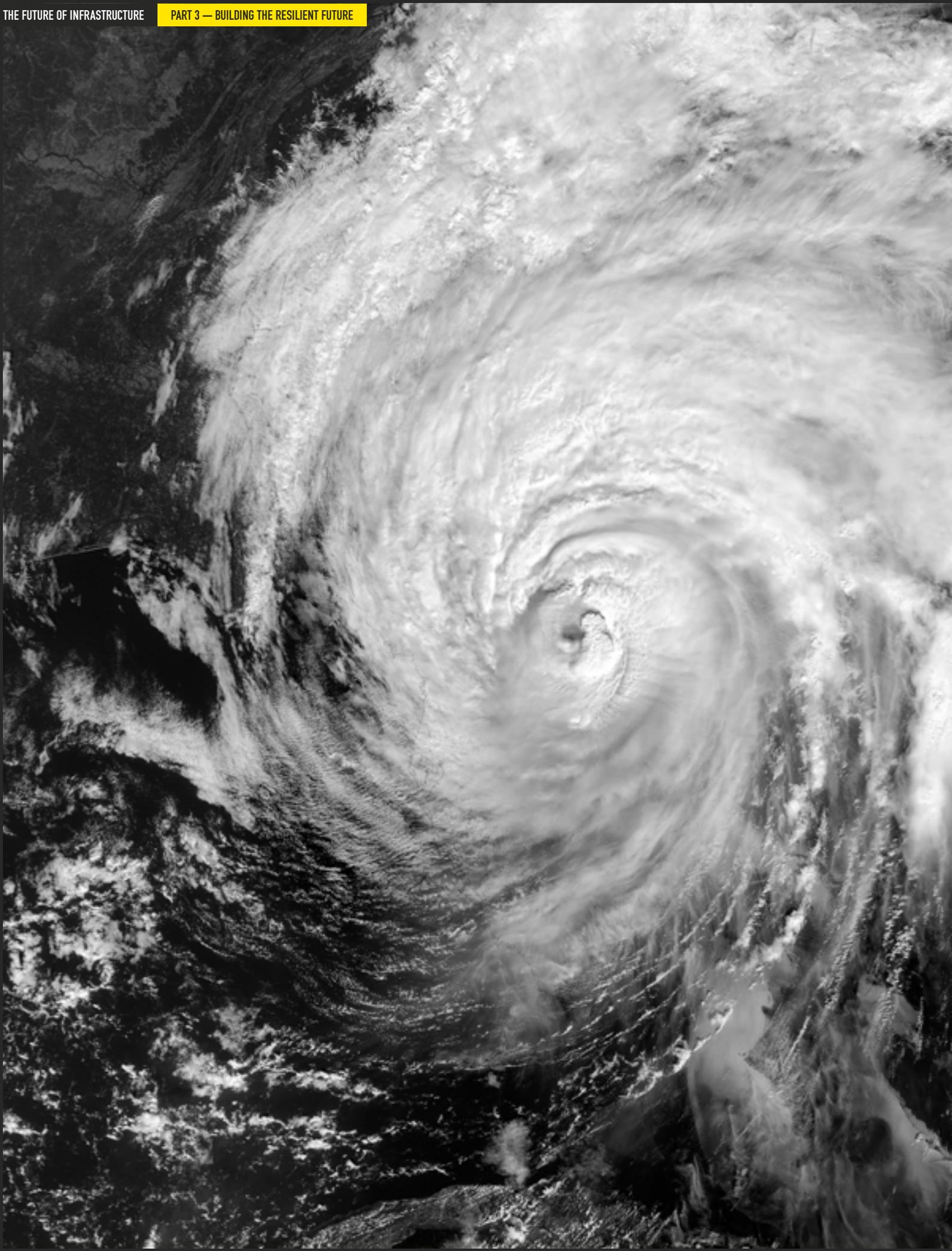
Data specialists — coders, programmers and analysts brought on board to harness the benefits of the latest technologies, and mine the growing volumes of smart data being generated for insights.

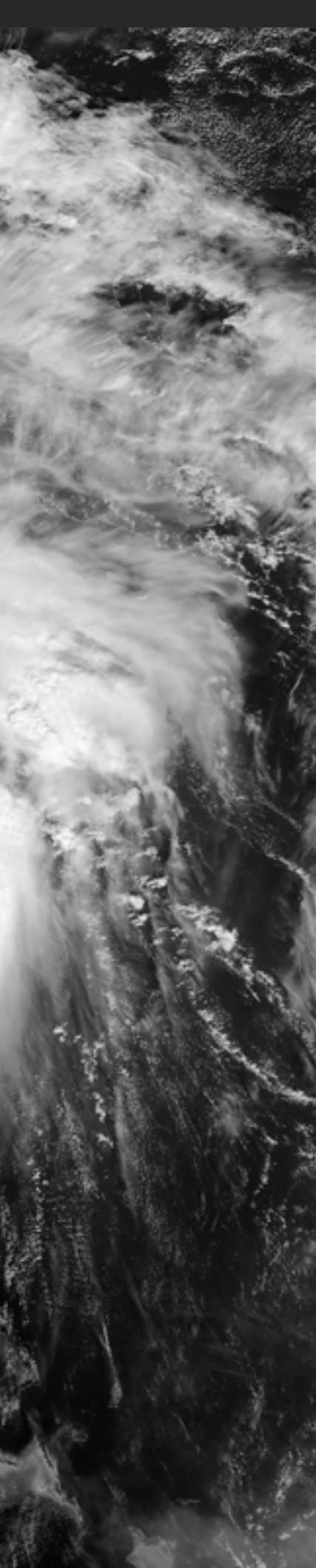
Client advisors — strong communicators focused on providing the best in customer service, and working as the face of their organizations.

5/ AGILE AND CULTURALLY AWARE

With projects now crossing continents, and global trends such as urbanization and aging demographics driving the speed of change even further, the future engineer must be able to respond rapidly to the latest industry developments and tailor their ways of working to the diverse needs of international clients. [WU](#)







Part Three

Building the Resilient Future

In brief

01/ Around one-third of industry leaders believe a major cyberattack is almost certain to happen in the near future

02/ A high proportion of infrastructure professionals feel ill equipped to deal with major events

03/ To support economic growth and social prosperity, future proofing and protection against cyber and physical attack are essential

04/ Early investment will help mitigate the significant repair costs after cyber- or climate-related disruptions

It is easy to get excited about the future. We all like to imagine a world of autonomous cars, digital railways that anticipate and help improve reliability, and Hyperloop links to usher in a whole new way of traveling.

Yet autonomous cars need roads to drive on, and digital rail systems and Hyperloop links have to interact seamlessly with legacy transport networks. When our survey respondents were asked about the infrastructure trends that will define the sector over the next five years, such non-traditional and disruptive projects ranked close behind the more predictable “hygiene” projects relating to essential services.

Infrastructure owners — as well as those entrusted with delivering projects — must find ways to keep pace with technological change. This will require clear, long-term thinking from both central and local government. Private-sector providers will also need to be incentivized to help find solutions for a growing array of complex problems.

We need to upgrade existing networks and systems as well as create new ones; embrace innovation in the ways we work and the infrastructure we rely on; and ensure that the infrastructure we create is resilient and future proofed to help withstand the shocks and stresses to come.

Cyber: A countdown to catastrophe?

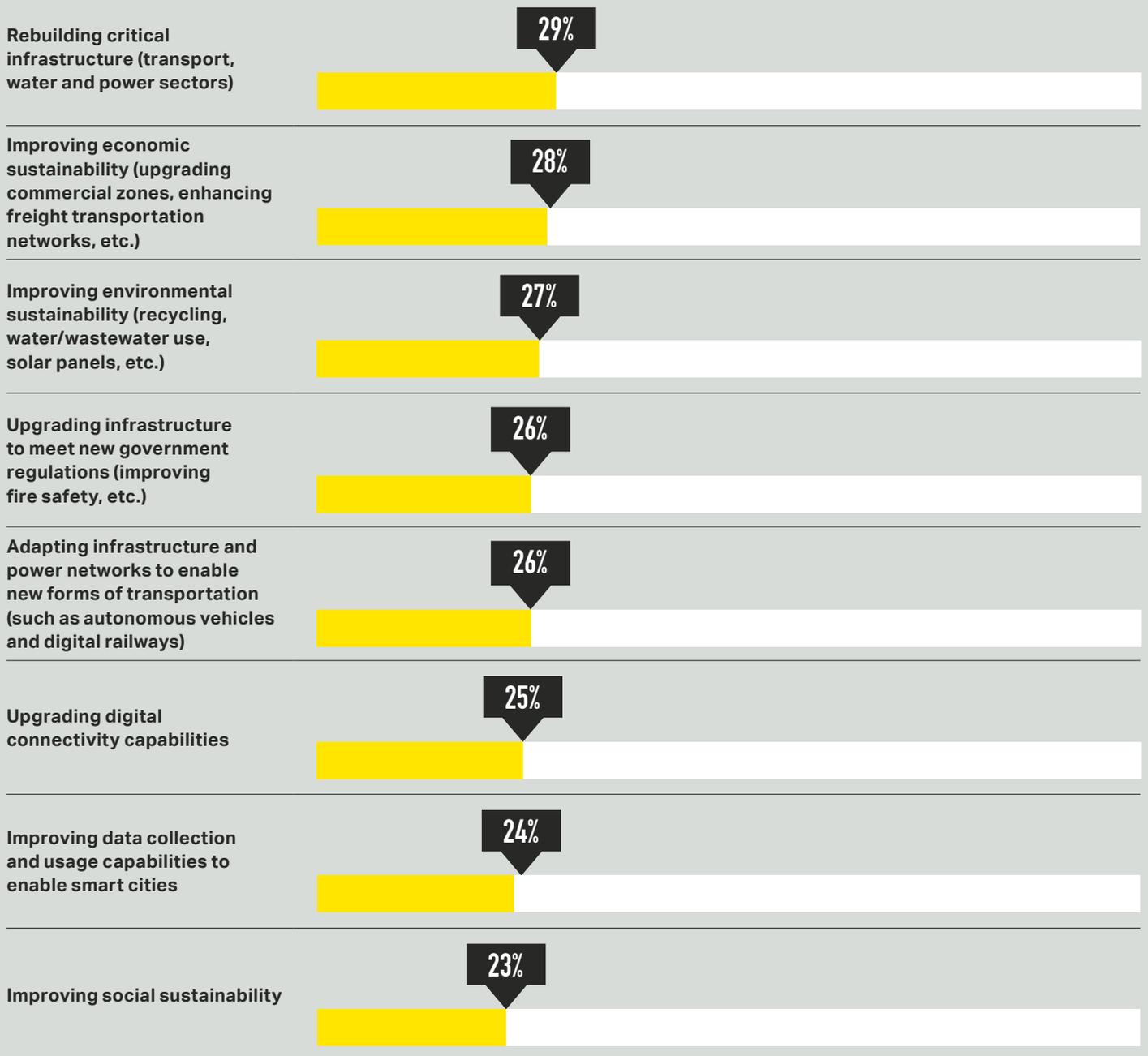
In today’s digital world, protection against cyberattack is one of the most critical aspects of resilience. When asked about the likelihood of certain events occurring in the next five years, respondents give a sobering assessment. About one in three believes that catastrophic events — a major ransomware attack or city-wide transport disruption — are almost certain in the near future.

The fact that many industry professionals don’t feel equipped to deal with this growing menace is troubling. Three quarters of respondents are highly pessimistic about their peers’ ability to anticipate a full-scale cyber event, and little more than half feel prepared to manage the cyberthreat overall.

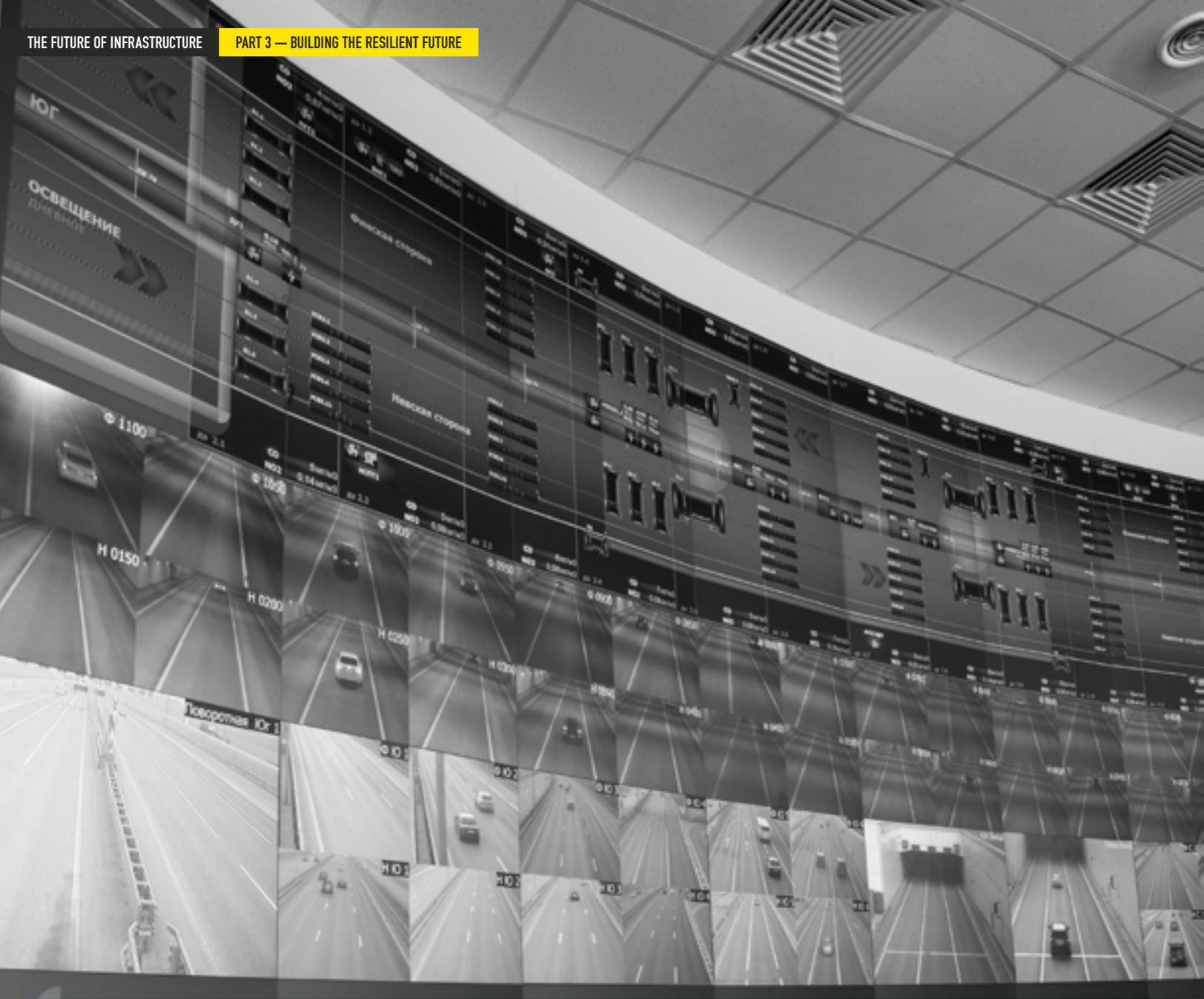
Infrastructure must be modernized, and the industry must become better informed about ensuring resilience and arming itself with relevant future-proofed skills.

Figure 10/

Respondents who see these as major infrastructure trends in the coming five years



 Agree



A GLOBAL PERSPECTIVE

Infrastructure resilience:

Views drawn from around the globe show different states of readiness for technological change and dealing with cyberterrorism

Technology: Disruptive to all

Tackling technological change is a common concern for industry professionals worldwide.

In both APAC and Europe, 66 percent of respondents feel that their countries' major cities are under-prepared for the impact of technological change on civil infrastructure. Some 65 percent of North American professionals share that concern.

Some are better prepared than others

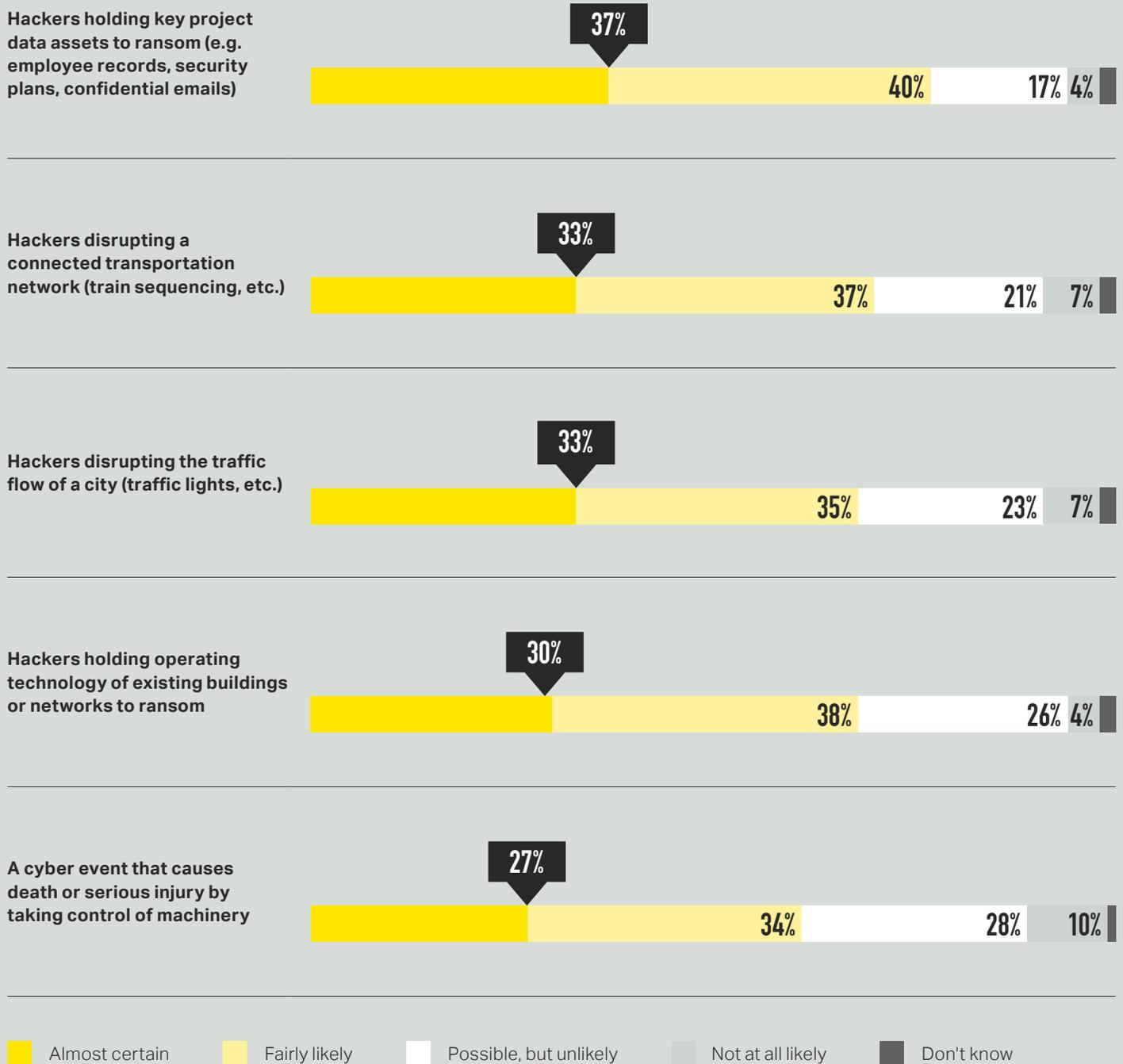
North American infrastructure professionals feel better prepared than their international counterparts to manage a growing cyberthreat.

Two-thirds (66%) of U.S. and Canadian survey respondents believe the industry is well placed to meet the threat of cyberterrorism, compared with 54 percent of APAC participants and 35 percent of those based in Europe.

For insight on infrastructure resilience, see **Resilience: In a Shifting World** on page 54

Figure 11/

How respondents rate the likelihood of several major cyber events taking place in the next five years





Lack of preparedness may put some systems at particular risk. Cyberterrorist groups are playing on the fact that some of our systems are dated and, therefore, not as secure as some of the more modern systems. Obviously, the solution involves not presenting ourselves as an attractive target.”

—
Peter Rogoff, Chief Executive Officer, Sound Transit

Essential innovation

Infrastructure professionals are aware of the unique economic and social sustainability role facing the industry over the coming decade. But new ideas and approaches are needed for industry players to prepare for what is to come.

There are signs that governments are waking up to innovation. The U.K.'s Digital Built Britain,¹ a program launched in 2015, encourages widespread adoption of new technologies and industry approaches — above all, the use of building information modeling (BIM), the internet of things (IoT) and advanced data analytics.²

Another U.K. government initiative, the National Infrastructure Commission (NIC), was formed to explore how breakthroughs in artificial intelligence (AI) can

increase productivity across the infrastructure network. The goal is to develop solutions for asset management, water efficiency, traffic management and the use of big data.³

The academic sector may also have a key role to play in advancing new solutions. Founded in 2002, the Centre for Innovation in Construction & Infrastructure Development (CICID) at The University of Hong Kong is helping to identify and disseminate strategies and methodologies from infrastructure innovation. The center also supports interdisciplinary research and has established a knowledge base of major infrastructure projects.⁴

Integrating new technologies can have a secondary benefit: attracting new talent. It can help solve the sector's image problem and create a virtuous circle — an influx of new

1 IN 3

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technical skills attracts younger generations who, in turn, increase the tech skills and freshen up the image even further.

Ideas from business

Of the more than 500 industry professionals surveyed, the vast majority share a clear appetite for deeper engagement with the private sector — particularly when it comes to technology and innovation, but also sustainability and resilience more broadly.

Nearly one-quarter of respondents believe that creating incentives for private-sector innovation will make the greatest difference in driving new technology solutions within civil infrastructure. A substantial proportion think it will be key to meeting future sustainability challenges.



The private sector is leading a lot of interesting discussions on innovation in infrastructure. This is a very positive thing. How the marriage between public and private happens in the U.S. is in a state of transition. As a public-sector leader, this is one of the more pressing things that we need to get our heads around.”

—
Therese McMillan, Chief Planning Officer, Los Angeles County Metropolitan Transportation Authority (LA Metro)

¹ <http://digital-built-britain.com>

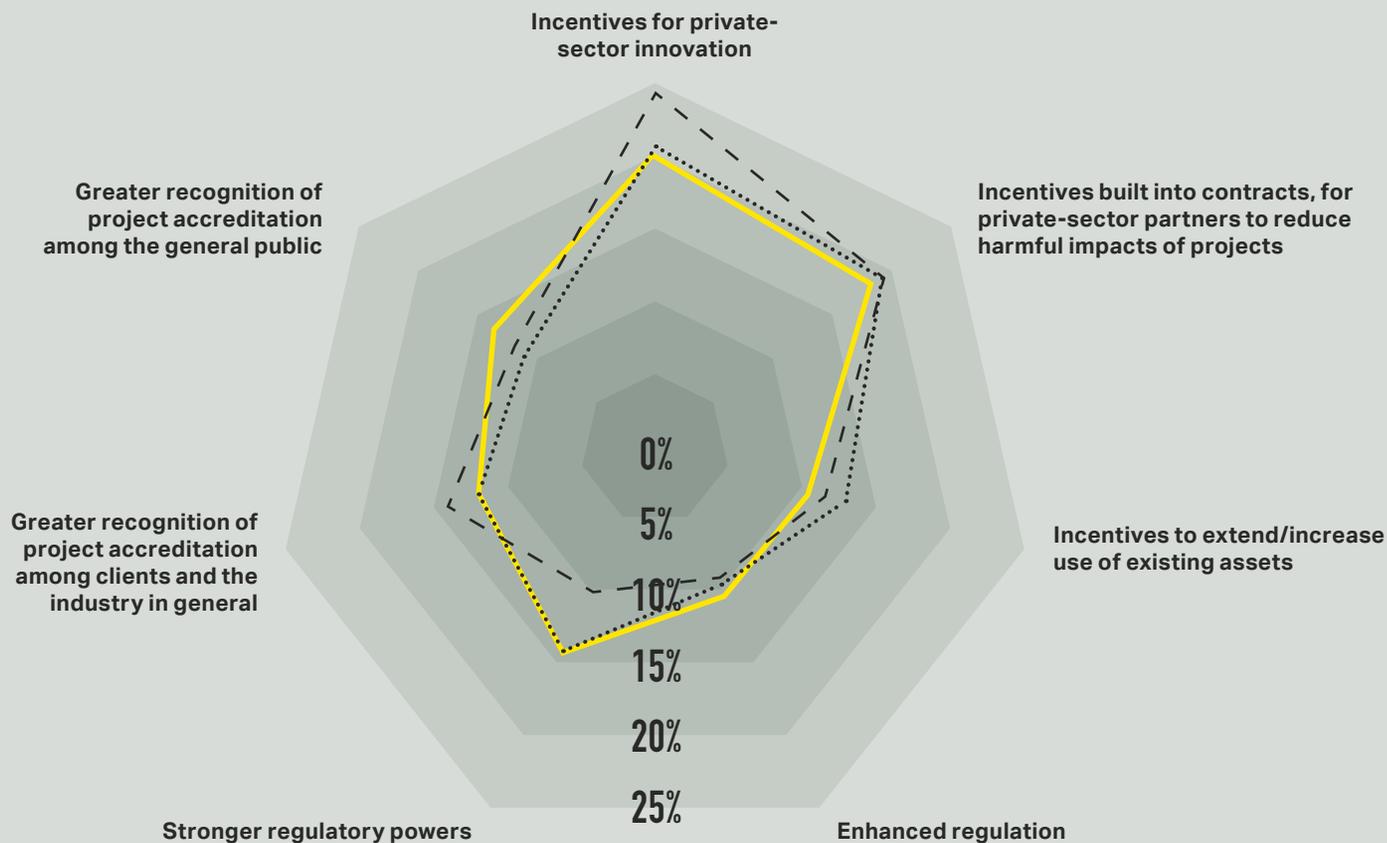
² https://www.designingbuildings.co.uk/wiki/digital_built_britain

³ <https://www.nic.org.uk/driving-innovation-in-infrastructure-through-artificial-intelligence>

⁴ http://www.civil.hku.hk/cicid/1_about_cicid.htm

Figure 12/

Proportions of respondents that say these initiatives would make the greatest difference to key areas of organizational behavior



..... Implementation of sustainability

— Implementation of resilience

- - Technology

RESILIENCE: IN A SHIFTING WORLD

The new generation of infrastructure will be smarter and more efficient, but with high performance also comes vulnerability. Future proofing and designing resilience into civil infrastructure projects is one of the biggest challenges facing the industry, write resilience experts **Ronald Hahn** and **Josh Sawislak**.



Safe, secure and resilient infrastructure is a lifeline to our future. It is the differentiator between successful and struggling economies and societies. So it is not surprising that much hope and expectation is resting on the new era of development.

No one can argue with the facts that demand currently outstrips supply, that existing networks and systems are under strain, and that massive investment, innovation and industry change is required to secure the US\$94 trillion of global infrastructure funding that — according to the G20's Global Infrastructure Hub — is needed by 2040.

But just adding capacity is not enough. To be durable and future proof, the infrastructure of tomorrow must cope with, and adapt to, a complex, extensive and evolving mix of hazards, risks and threats. As a result, resilience must now be an essential component of every project across its entire life cycle — integrated from the planning and design phase — and not just added on as a last-minute feature.

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—

The price of progress

While there is agreement that embracing innovation and the use of digital tools will be invaluable, our growing digital dependency has led to fears about the impact of hackers disrupting critical infrastructure.

In AECOM's Future of Infrastructure research, industry respondents were in no doubt about the challenges ahead, particularly in terms of cyber and terrorist attacks and the negative impacts of climate change.

Approximately one in three infrastructure professionals believes that cyber-related catastrophic events — including city-wide transport disruption and even deaths — are a certainty in the near future.

Their concerns are reflected in research by cybersecurity firm Kaspersky Lab, which found that 40 percent of the world's infrastructure had been the subject of a cyberattack during the second half of 2016.¹ Meanwhile, in the U.K., government statistics in the Cyber Security Breaches Survey 2017 reveal that almost seven in 10 large companies identified a breach or attack in the previous year.

Infrastructure resilience

What's more, civil infrastructure must also withstand the escalating physical threats of terrorism and climate change. For these combined reasons, ensuring the resilience of civil infrastructure is one of the biggest challenges facing the industry.

Physical acts of terror (kinetic terrorism) features prominently in the industry's concerns. Some 55 percent of professionals questioned in the Future of Infrastructure research believe the industry is prepared to manage the threat of attacks on critical buildings and transport links.

Globally, we're seeing an uptick in the number of terrorist threats, as well as the use of unanticipated methods. These threats have evolved significantly over the last decade — much of the infrastructure we rely on was neither designed nor built for such threats.

The challenges posed by the natural world are no less worrying. Extreme weather events and natural disasters are two of the most likely and impactful risks identified in the World Economic Forum's 2017 Global Risks report.² ➔

¹ <https://www.infosecurity-magazine.com/news/40-of-ics-critical-infrastructure/>

² http://www3.weforum.org/docs/GRR17_Report_web.pdf



And the United Nations ³ estimates that the global cost of natural disasters from 2003 to 2013 was US\$1.5 trillion, and that these disasters affected more than two billion people. Climate models predict increases in the frequency and severity of these types of events, so we can expect to see the costs and human impact rise. In just the past year, hurricanes in the U.S. and the Caribbean alone have caused more than US\$265 billion in damage so far, with the full scope of the damage and recovery costs still being assessed.

When two worlds collide

Most worrying of all is that these two classes of threat — the physical and the digital — are rapidly converging.

In the era of smart cities, wide-scale adoption of the internet of things (IoT) and cloud technology all offer significant advantages



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across the built environment, from increasing communicability and maintenance monitoring to reducing traffic congestion.

Yet this increased digital access also makes infrastructure assets more vulnerable. In recent high-profile and large-scale cyberattacks, we saw disrupted power supplies, government departments and banks in Ukraine along with the U.S., U.K., Australia, Russia and others. It was reported that in Ukraine, hackers were able to infiltrate several of the country's power distribution centers, leaving more than 250,000 residents without electricity. ⁴

These attacks have the potential to become even more destructive. For example, the Center for Strategic and International Studies ⁵ believes that North Korea is building its cyber resources and is “capable of conducting damaging and disruptive

cyberattacks” — as the recent attacks, attributed to North Korea, against Sony Pictures Entertainment and financial and media institutions in South Korea have shown.

Conversely, physical threats, such as those resulting from climate change, can also pave the way for digital disruption. There is a far greater symbiosis between the digital and physical worlds than most people realize. Buildings and structures become more vulnerable to cyber or kinetic attack during a natural disaster.

The effects of natural disasters that impact critical infrastructure, such as power, water, wastewater and communications, rely on our digital backbone to function. Without access to the digital backbone, the ability to restore basic infrastructure functions is dramatically reduced or prevented altogether.

³ <http://www.fao.org/3/a-i5128e.pdf>

⁴ <https://www.wired.com/2016/03/inside-cunning-unprecedented-hack-ukraines-power-grid>

⁵ https://csis-prod.s3.amazonaws.com/s3fs-public/legacy_files/files/publication/151123_Cha_NorthKoreaCyber_handout_final.pdf

⁶ <https://www.fsb-tcfd.org/wp-content/uploads/2017/06/FINAL-TCFD-Report-062817.pdf>

⁷ <http://www.fsb.org/>

⁸ https://www.eiuperspectives.economist.com/sites/default/files/The%20cost%20of%20inaction_0.pdf

⁹ <https://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/risk-and-responsibility-in-a-hyperconnected-world-implications-for-enterprises>

¹⁰ http://www.swissre.com/media/news_releases/nr20171220_sigma_estimates.html

¹¹ <http://www.garnautreview.org.au/update-2011/garnaut-review-2011.html>

¹² <https://www.bloomberg.com/news/articles/2017-07-18/global-cyber-attack-could-cost-121-4-billion-loyd-s-estimates>

¹³ https://www.start.umd.edu/pubs/DHS_%26A_GTD_Targeting%20Critical%20Infrastructure%20in%20the%20US_June2016.pdf



THERE IS A FAR GREATER SYMBIOSIS BETWEEN THE DIGITAL AND PHYSICAL WORLDS THAN MOST PEOPLE REALIZE. BUILDINGS AND STRUCTURES BECOME MORE VULNERABLE TO CYBER OR KINETIC ATTACK DURING A NATURAL DISASTER.

Where do responsibilities lie?

As the threats to critical assets evolve, the resiliency strategies of infrastructure owners and service providers have not kept pace.

The industry professionals surveyed by AECOM are candid about their industries' abilities and inabilities when it comes to withstanding emerging threats. Most respondents cite infrastructure resilience to cyberattacks and climate change as key priorities when planning major projects. But no more than six in 10 feel the industry is well prepared to meet these risks.

A lack of definitive resilience solutions may be due in part to the fragmented nature of today's infrastructure landscape. As national, regional and city governments struggle to pay for new and upgraded critical infrastructure, they are more frequently looking to various forms of ownership and risk transfer to the private sector.

Business-critical resilience investment

We are starting to see the global financial markets ask questions about how to assess and price the impacts of climate change. As the 2017 report from the industry-led Task Force on Climate-related Financial Disclosures⁶ highlighted, there is increasing demand for improved climate-related disclosures.

The markets want to understand how it affects impacts on physical assets, liability and the cost of stranded assets (transition risk).

In response, the Task Force, established by the Financial Stability Board,⁷ consulted with financial and business leaders to identify a new, accessible framework⁶ for climate-related financial disclosures to inform better pricing of these types of risks.

As the financial services industry matures its treatment of infrastructure risk, weak resilience planning will increase costs and lower value for asset owners through borrowing, and insurance costs and valuation.

Likewise, investors and rating agencies will increasingly require organizations to demonstrate their capability to manage the threat of attacks or extreme weather events. Those able to demonstrate resilience will enjoy significant advantages, and negotiate discounted premiums.

Converged Resilience™ — an industry game changer

The changing infrastructure landscape has created the need for holistic, industry-wide solutions for identifying and managing risks. Resilience is not a one-dimensional or static issue, and successful attacks find and exploit vulnerability.

AECOM has developed a holistic approach called Converged Resilience™, which acknowledges the interdependency of the physical and digital worlds — and uses this understanding to build lasting, integrated strategies for infrastructure resilience.

As any risk manager will confirm, risk cannot be eliminated altogether; however, we believe that infrastructure owners and service providers — both public and private — can become better at planning for and mitigating threats, including those as yet unknown. The goal should be to manage risk effectively, understand which risks, at what level, should be mitigated or transferred, and even accept some risk.

So, what should infrastructure organizations do to prepare to manage these risks effectively? →

COUNTING THE COST

The price of non resilience

US\$4.2 TRILLION

The expected value of at-risk losses to manageable global infrastructure assets from a 2°C rise in average temperatures (in present value terms). The Economist, 2015.⁸

US\$3 TRILLION

Projected cost of low cyber-resiliency on global productivity and growth by 2020. McKinsey, 2014.⁹

US\$306 BILLION

Total economic losses from natural and man-made disasters in 2017 are estimated to be US\$306 billion, up from US\$188 billion in 2016. Swiss Re.¹⁰

0.5%

Projected economic cost to Australia's annual GDP of unmitigated climate change by 2020 (rising to 1.2 percent in 2050). Garnaut Climate Change Review, 2011.¹¹

US\$121 BILLION

Potential cost of a worldwide cyberattack. Lloyd's of London, 2017.¹²

1,986

Number of terrorist attacks targeting critical infrastructure occurring in the United States during 1970–2015. National Consortium for the Study of Terrorism and Responses to Terrorism, 2016.¹³

5 POINT PLAN FOR A CONVERGED RESILIENCE™ FRAMEWORK

Converged Resilience™ provides the approach for a lasting resiliency strategy. While each organization and situation is different, it is possible to apply a common framework to the problem. The goal is to simplify the risk-management process while allowing the flexibility to cope with a broad range of scenarios across both the digital and physical environments.

1/ START EARLY

For maximum impact, a resiliency strategy must be introduced as early as possible in the lifespan of an asset. The industry has often viewed resilience as an add-on to the core design-build process, and that is too late.

This may link back to the industry's binary view of the physical and digital worlds. We still see examples, such as during the construction of an airport building or a rail track — when plans for introducing the IT and security systems are started after the physical asset has been built.

For infrastructure owners, the goal must be to build in resilience planning as early as possible — the sooner a protection framework is implemented, the more cost efficient and effective it becomes.

2/ UNDERSTAND THE RISK

Having early-stage conversations about risk management makes it easier for an organization to customize a resiliency strategy. First, this means knowing which assets it wants to protect, as well as, more importantly, understanding the function of those assets and the potential cost of losing or devolving that function. Beyond simple replacement cost, what is the business case for determining which assets to protect and how?

Through efforts such as the 100 Resilient Cities program¹⁴ (100RC) pioneered by the Rockefeller Foundation, municipalities are taking a strategic approach to understanding, not only the risks, but also the interaction of the risks and different urban systems and goals. Resilience strategies will help cities and companies fully integrate resilience into all of their efforts — from the earliest stages of planning and development — as well as assess what should be retrofitted.

¹⁴ <http://www.100resilientcities.org/focus-impact-evidence-first-four-years>

¹⁵ http://www.keepeek.com/Digital-Asset-Management/oced/economics/investing-in-climate-investing-in-growth_9789264273528-en#page104

3/ PRIORITIZE TO OPTIMIZE

It is impossible to eliminate risk completely.

If its assets are aging, an infrastructure owner will need to select where it wants to focus its resiliency investment. Consider where most effort and resources need to be focused.

In addition to functionality, the service life of an asset and the feasibility of replacing it must come into consideration. For example, a manufacturing plant for airplane parts may have a 40-year service life. The time and cost of replacing such a facility is tremendous, so the owner will want to make a significant investment in keeping it running throughout its design life. By contrast, a data center with hardware assets that are replaced every two years will have less at risk, as its long-term asset is only the building that houses the equipment.

4/ ACCEPT, MITIGATE OR TRANSFER

With new vulnerabilities constantly evolving, infrastructure owners must decide how to manage the many risks they face.

The first option is to accept the risk and manage it internally with the resources available. A second option is mitigating risk as new threats emerge by adapting or retrofitting an asset. The goal is to restore functionality, either fully or partially, in the fastest time.

The third approach is to transfer the risk; for example, by creating a back-up facility that can quickly take on the functionality of the original asset. When this is not feasible, a company or municipality may look to transfer a much larger proportion of risk to the insurance market.

It is important to understand, however, where that risk is transferred in order to ensure it is managed effectively. For example, leasing a second data line into a facility from a different provider than the primary line may transfer risk, but only if it is a different physical path that is not connected to the primary line.

5/ ENHANCE

Building infrastructure resilience cannot be a one-time investment. Just as being healthy requires a certain lifestyle, resilience demands a new way of operating.

Having put a strategy in place, it is essential that the protection plan is revisited and updated regularly. Continuous risk mitigation must be the goal. The threats are constantly evolving. Business changes, government changes, environments change, compliance increases, technology is exploding — it is crucial to stay engaged and agile.

Conclusion: Opportunity out of adversity

Investing in infrastructure resilience can be an expensive and time-intensive process, but it is a necessary one. Early planning not only mitigates the impacts of disruption, it also creates interesting net benefits. For example, the introduction of on-site renewable energy into an organization's energy mix creates distributed generation. This is effective, as it introduces resilience into the grid. At the same time, there are enormous benefits from a sustainability- and fuel-reduction standpoint, and it can create a hedge to fluctuations in energy costs.

Looking at the bigger picture, infrastructure-focused, climate-change initiatives have the potential to offer positive effects for the wider global economy while generating market advantages and goodwill with customers, employees and investors.

According to OECD projections, the infrastructure investments needed to support the shift toward a low-emission society would generate fuel savings of up to US\$1.7 trillion a year worldwide through 2030.¹⁵

Organizations of all shapes and sizes should take heed. Risk affects every one of us. The public and private sectors have a responsibility — whether it is to their shareholders or constituents — to balance the books and to generate growth. Building resilience is a critical part of this business case. [WU](#)

STRANGER THAN FICTION:

A DAY IN THE LIFE OF FUTURE INFRASTRUCTURE

From the Jetsons to Futurama, and Star Trek to Blade Runner, we've all seen imagined futures filled with flying, driverless cars, homes run by artificial intelligence (AI), and supersonic travel. As new technologies make these ideas a reality and revolutionize future infrastructure, **Veronica Siranosian** and **Andrew Bui** from the AECOM Ventures team look at some of the biggest emerging infrastructure trends and imagine a day in the life in 2030.

In a city in 2030, it's morning. The built world around you has transformed in the last decade or so, reshaped by the Fourth Industrial Revolution, and continues to evolve at unprecedented speed. You're asleep in your new environmentally efficient home, constructed more durably, precisely and cost-effectively than homes built just a few years ago, due in large part to 3D printing technologies. It's time to get up.

A world designed for you

Slowly, the blinds covering the solar windows in your bedroom begin to rise. It's a winter morning, and the lighting and temperature controls within your home automatically respond to the elements outside.

Every fitting, fixture and feature in your home is designed to sense and react to your needs, helping you run your life as smoothly as possible. Some, such as your smart walls, are made of programmable materials that respond to external stimuli. Others are directed by sensors controlled by you with just a word or flick of the wrist.

This means no more stumbling around in the dark on cold mornings, searching for the light switch, or sweltering during hot summers. Now, whatever the time of day or year, the lighting, temperature and atmosphere



in your home will always be just how you like it.

As you blink awake, you wave your hand and turn on two of the translucent screens close by. One brings up your virtual assistant, and you share some late-night thoughts you had to email to a colleague.

The other screen displays the morning's headlines.

Managing water, sustaining life

For once, it's good news. Climate change continues to increase the intensity and unpredictability of extreme weather events like floods and droughts. But the story today is that a flood forecasting and early warning system in the Kosi River Basin — one of the most vulnerable sites to flooding in India — will help to divert a disaster, protecting communities and saving thousands of lives during the heavy monsoon seasons in the coming years.

The system uses a web-based solution to analyze the 72-hour weather forecast, rainfall data and other real-time, hydro-meteorological information fed into mathematical models. When the risk of flooding is near or beyond danger levels, the system will automatically alert officials to prepare their emergency response efforts and communities' defenses ahead of time.



EVERY FITTING, FIXTURE AND FEATURE IN YOUR HOME IS DESIGNED TO SENSE AND REACT TO YOUR NEEDS.

Not a drop or watt wasted

At the same time, the world can't afford for this excess water to go to waste. The demand for fresh water is rising¹ as the global population grows. Farmers need it to boost food production, and power stations to generate energy. But we're draining resources faster than they can be replenished.²

Many like you rely, in part, on systems built into your homes, offices and other facilities to capture, store and treat rainwater for everyday use. Some countries are exploring building ecosystems that will enable the transfer of flood water to storage reservoirs, so that it can be used by drought-hit areas elsewhere.

Tighter emissions regulations around the world are also driving innovation and investment in the treatment and reuse of water, aiming to reduce the need to abstract it from rivers and other natural water resources.

In response, the water industry has worked to upgrade its infrastructure and employ solutions like IFAS (Integrated Fixed-Film Activated Sludge) technology — which enables them to intensify their treatment processes, using their existing assets, without increasing their costs or footprint.

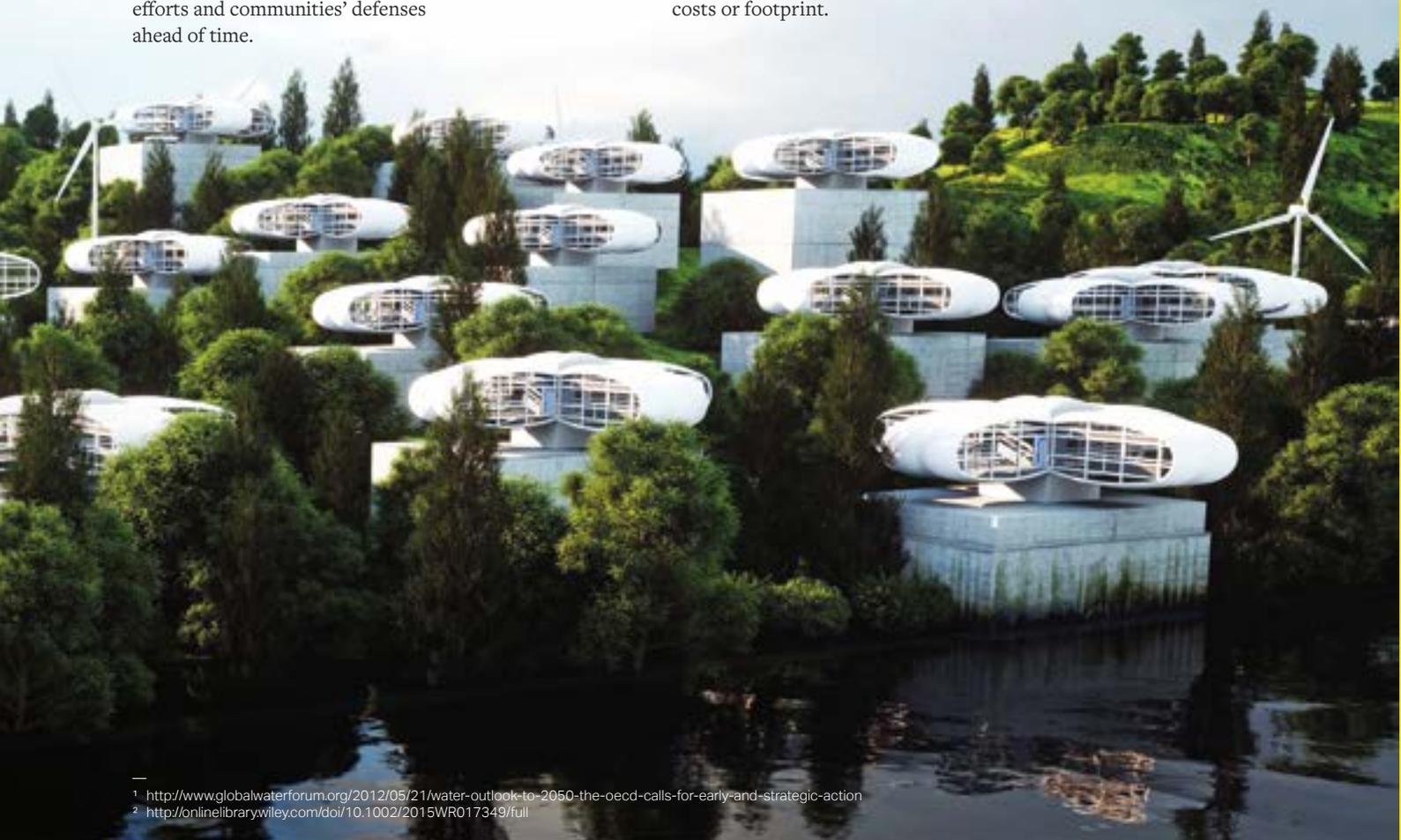
Other advances include the use of microbubbles. Water companies pump air into wastewater, creating bubbles to rapidly break down sewage. This technology, which can be fitted to new and existing treatment plants, generates smaller bubbles to complete this purification process cheaper, faster and more sustainably than ever before.

And, most recently, the industry is drawing on microbubbles to strip out ammonia from drinking water and turn it directly into fertilizer, removing the need for previously costly additional stages.

Power stations, too, are increasingly becoming a thing of the past. More and more homes — including your own — are powered by super batteries that store and use energy generated via solar panels and other renewable solutions.

Flexible homes, healthier lives

As you step into the bathroom, you check your own fresh water stores and limit yourself to a three-minute shower — before getting dressed. When you're finished, you grab that day's outfit. It not only adapts to fit your body shape, but also helps you monitor your physical health and mental wellbeing, sending regular updates to your phone. →



¹ <http://www.globalwaterforum.org/2012/05/21/water-outlook-to-2050-the-oecd-calls-for-early-and-strategic-action>

² <http://onlineibrary.wiley.com/doi/10.1002/2015WR017349/full>



This morning's message is that you need more vitamin C, and it offers suggestions for different juice recipes. You select one and send it to your smart juicer. It's ready by the time you get to your kitchen, alongside a pot of freshly brewed coffee. You grab a cup and some breakfast.

A friend is due to visit this weekend. Before leaving, you rearrange your living space, moving the flexible internal walls of your home to create a spare bedroom, and add a request to make up a bed to your home droid's list of chores for the day.

Space for living

Currently, your home is located in a central community hub, and every day the use of the space around you is evolving.

More people are relying on walking, biking, public transportation, and mobility-as-a-service (MaaS) providers — who operate fleets of autonomous electric vehicles³ — as faster, safer and cheaper alternatives to owning their own car. As a result, chunks of urban and curbside real estate once filled with vehicles are reclaimed for the community.

In fact, your new home is located in a former multi-story parking lot, now repurposed in record time using 3D printing technologies to provide access to sustainable, affordable homes for the city's growing population, as well as a public gym and other local facilities.

On a smaller scale, others are adapting their old garages to be used as drop-in workspaces. On the days you don't commute, you log into an app to check local availability for a temporary desk. Today, you're needed in the office.

Putting your best foot forward

You set off to your nearest mobility hub — this includes the options to take public transportation, or share a ride via a MaaS journey — your transit agency app alerts you that your usual multi-modal journey has changed, due to an all-day concert in the park. So, you acknowledge and confirm your travel preferences, and the app advises you of your new journey, which now includes a shared, electric, connected and autonomous vehicle (CAV).⁴

Transport systems across the world are now using artificial intelligence (AI) and digital sensors to help analyze the millions of pieces of data being generated relating to demand, delays and constraint issues across their networks and respond with increased capacity, timetable changes and updates to passengers in real time.

It's good to talk

These vehicles are available on demand and provide dynamic routing based on passenger origins and destinations in real time. It's waiting to pick you up when you get to the hub.

The introduction of CAVs, combined with MaaS, improved "connected vehicle" services, shared vehicle use, and sustainable fuels will revolutionize transport. It will improve safety, ease congestion, improve air quality and increase social inclusion, mobility options and access.

In the past, traffic accidents, largely caused by human error, killed more than 1.2 million people globally every year and injured millions more.⁵

Connected vehicle technologies allow transport systems, roads, infrastructure and smart devices to speak to, alert each other and process big data to enable connected vehicle services (such



YOU ORDERED YOUR NEW HOME ONLINE JUST OVER SIX WEEKS AGO. WITHIN DAYS, A 3D CONCRETE PRINTING ROBOT HAD PRODUCED THE WALLS, ROOF AND FLOORS.

as smart routing, for example). Automated technologies enable vehicles to respond in real time to this and other information, without driver input, and avoid potential dangers, such as missed red lights, speeding vehicles and sudden stops, as well as congestion or travel issues.

These vehicles have also helped to increase the mobility of people unable to access or use traditional vehicles in the past, including older people, those with disabilities or those in more rural or lower-density communities that may have been underserved by fixed-route transit.

Charge as you go

Smart powered lanes help CAVs to go the distance, using wireless technology that enables these vehicles to charge their batteries as they drive on the road at full speed, making range anxiety a thing of the past.

Importantly, any excess energy generated through these journeys can be used to power people's homes, workplaces and communities.

There are also sustainable fuel stations available that provide a network of electric charging stations and other fuels — where, in a matter of minutes, you can power up, grab a drink or even pick up parcels you've ordered online.

Future infrastructure that fixes itself

As you ride over a bridge, one of its smart sensors highlights a problem in the infrastructure, but it won't slow you down now or in the future. In minutes, the bridge's internal intelligence system alerts the maintenance team back at base to the fault, orders a replacement part to be 3D printed and delivered, and schedules the fix to be implemented.

Pods on demand

You carry on unaware. As your CAV bus drops you off at the nearest mobility hub to your office, you complete the last part of your journey with a Pod on Demand (PoD). These next-generation PoDs are a sustainable, cheap and fast way to move around, helping people, businesses and communities to better connect with each other.

In some areas, the vehicles operate in narrower lanes, freeing up vital space for walking and enhanced community and transportation facilities, such as bike-share stations, boosting people's travel options and freedom.

Your PoD moves seamlessly from road to sidewalk, directed by connected and autonomous technologies, navigating its way between pedestrians and other vehicles efficiently, safely and smoothly.

As you travel, you look out of the window and manage to make out a few of the skyscrapers' roofs now working as high-rise farms, with cows and sheep grazing in the clouds.

The only way is down

When you get to work, however, you don't go up. You go down. Urban real estate remains at a premium, driving many businesses to locate themselves in deep-basement offices. Your workspace is several floors in total, each one lower than the last, offering meeting rooms, restaurants and shops, as well as sleeping pods if you have to work late.

The energy-efficient trap lights, which run throughout the building, use photoluminescent pigments to capture and give out light. This, alongside a glass atrium, helps to keep the structure bright.

You find a desk and head to your first meeting. It's a catch up with colleagues, who beam in from around the world as holograms. You plug in your translation earbuds and join the discussion with ease.

Express delivery

At midday, you receive a call from a supplier letting you know that the goods you ordered that morning will be delivered in 30 minutes by Hyperloop. This high-speed technology enables goods and passengers to be transported comfortably and seamlessly in pods capable of traveling at subsonic speeds through low-pressure tubes.

Crossing hundreds of miles in a matter of minutes, people and businesses are no longer limited by their location. The Hyperloop system works in conjunction with other transit and pod systems, helping to balance and drive economic growth across the country.

A virtual journey

After lunch, you and a colleague plan for a major upcoming building project.

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CROSSING HUNDREDS OF MILES IN A MATTER OF MINUTES, PEOPLE AND BUSINESSES ARE NO LONGER LIMITED BY THEIR LOCATION.
—

Using augmented reality (AR), you digitally recreate the planned finished building, using photorealistic textures, materials and lighting to take a walk through the project. Incorporating digital building information modeling (BIM) data, you're able to highlight potential delays and issues, and contact other team members to discuss possible fixes — weeks before anyone steps on-site.

Catching a flight home

The afternoon passes quickly, and you stay a couple of extra hours to finish up some other projects. Tired, you head up to your office's vertiport to take an aviation taxi. Over the last decade, the sky above you has become busier — increasingly populated by delivery drones, running alongside flying autonomous vehicles, and governed by strict air traffic control rules and initiatives such as designated flight lanes and tolls.

After a short wait, your taxi — a lightweight, electric vertical take-off and landing aircraft — arrives to fly you home ready for tomorrow. **ML**



The Samson Switchblade
Image courtesy of Samson
www.samsonmotorworks.com

³ <http://www.aecom.com/blog/infrastructureweek-innovating-today-to-improve-how-we-get-there-tomorrow>

⁴ <http://www.metro-magazine.com/technology/article/724846/autonomous-vehicles-have-potential-to-deliver-array-of-benefits>

⁵ <http://www.who.int/mediacentre/factsheets/fs358/en/>

About this Research

This report has been produced by AECOM in collaboration with Longitude. It is based on two main inputs.

First, we conducted a survey of 509 civil infrastructure professionals from three regions: APAC, Europe and North America. Please note, the APAC region consists entirely of 50 respondents from Australia; (qualitative interviews include representatives from the wider region). Europe comprises 109 from the U.K., 45 from the Republic of Ireland, and five from Germany; and North America comprises 274 from the U.S. and 26 from Canada.

Respondents work in a range of sectors related to civil infrastructure. All respondents work on projects exceeding US\$100 million, and 43 percent work on projects exceeding US\$500 million.

The research was carried out online. Respondents were not compensated for their participation and AECOM was not identified as the research sponsor.

Second, we conducted qualitative interviews with a range of senior figures in the civil infrastructure industry. AECOM was identified to this group as the research sponsor.

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Disclaimer

AECOM would like to thank all clients, partners and project teams for their help in producing this publication. Every effort has been made to ensure accuracy, give credits and trace copyright holders where appropriate. If any have been inadvertently overlooked, the necessary arrangements will be made at the first opportunity to amend the publication.

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