



The global forces shaping the future of infrastructure

Global infrastructure trends

Introduction

The infrastructure sector sits at a collision point of global disruptions, including shifts in capital availability, evolving social and environmental priorities, and rapid urbanisation. However, the emergence of COVID-19 introduces an altogether new set of challenges. The full impact of the pandemic will take years to play out, but it has already sharpened the focus on risk and resilience across the industry. Looking beyond the immediate COVID-19 crisis, we examine the overarching forces that will shape the future of the infrastructure sector more broadly and over the long term. This report covers:



Four ways that COVID-19 could reshape the infrastructure industry. The fallout of the crisis will test the infrastructure sector in the short term, leading to changes in demand and specific impacts in operational resilience, technology, affordability and sustainability.



Developments in financing. The pressing global need for substantial infrastructure is widely recognised. The challenge isn't just to fund the massive investment required and target it at the right infrastructure projects. It's also necessary to provide the required infrastructure on an affordable, socially equitable and environmentally sustainable basis. To narrow the gap between funding availability and need, stakeholders across the industry will need to continue working together to innovate and to scale investment.



The impact of technology. Technology is disrupting the way infrastructure is used and the way capital projects are delivered. New and emerging technologies will be a big part of the solution to the world's infrastructure challenges. Accelerating the pace of technological progress and innovation on infrastructure projects will require a step change in policy focus, new financing solutions and business models, and more research and development.



The need for resilience and sustainability. Although the world's attention has most recently been focused on the COVID-19 global health crisis, the impacts of climate change and urbanisation continue to mount, and still pose significant challenges to which governments and the infrastructure community will need to respond.

Each of these forces would be disruptive on its own; collectively, they pose a huge challenge to the industry. Leadership teams need to understand these changes and take proactive steps to ensure they are building for the future. We believe they are up to the challenge.



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Four ways that COVID-19 could reshape the infrastructure industry



In October 2019, we asked infrastructure CEOs across the world to look ahead to 2020.¹ Though most said they were expecting the pace of economic growth to slow during the year and were planning their growth strategies accordingly, nobody could have anticipated the COVID-19 pandemic. Given the crisis's sudden sharp impacts and the potentially long duration of intensity, the economic fallout of the crisis will test the resilience of the infrastructure sector.

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Lockdown measures resulted in a sudden decline in public transport and road infrastructure usage, causing formerly stable revenues to diminish and calling into question transport and utility current operating models.



A dramatic decline in demand

The forced cessation of travel, disruptions to supply chains and changes in consumer behaviour are among the COVID-19 impacts that are affecting every sector of infrastructure. Lockdown measures resulted in a sudden decline in public transport and road infrastructure usage, causing formerly stable revenues to diminish and calling into question transport and utility current operating models. Against this background, transport asset owners are wondering whether the sudden move to remote working will lead to a permanent shift in working patterns, with consequent impacts on other industries, such as real estate. The shutdown could also lead to a shift from mass transit to micromobility options, such as dockless bikes and scooters, which would affect future infrastructure planning.

Questions are also being raised about the air travel and freight industries. If usage of air transport declines significantly, will the aviation sector need to consider fundamental changes in how airports are designed and built? And what would a switch to more localised supply chains do to volumes and demand for port owners and operators?

The power sector is not immune either. In the UK, for example, overall demand for electricity has declined due to the lockdown. As a recent PwC study has highlighted, the coincidence of COVID-19 with an oil price crash in March 2020 is likely to affect the transition to renewable energy in the short term, with cheap oil lessening the attractiveness of investment in renewables, because oil-run generators will be more cost-effective.²

It's impossible to map out how the crisis will ultimately affect the infrastructure sector as a whole. But we believe the most immediate effects will be felt in four areas: operational resilience, technology adoption, affordability and sustainability.

Operational resilience

The COVID-19 outbreak has brought operational resilience into sharp focus, particularly by exposing the fragility of supply chains. The Western reliance on Asian manufacturing has never been more apparent, as companies have had to quickly identify secondary suppliers, preferably local ones, because logistics options were also closed off.



Supply value chains cannot be established overnight — especially complex, globalised material supply chains of the kind required for large-scale capital projects. And the redesign of supply chains is likely not feasible in the current disruptive environment. Yet once the immediate crisis has passed, infrastructure CEOs will need to rethink their supply chains to build in as much resilience to global shocks and disruptions as possible.

Alongside some more obvious steps — such as a shift away from sole-supplier relationships³ (be they with individual countries or companies) — we could see developments such as

- the introduction of new assessment criteria, such as responsiveness and resilience (along with more comprehensive business continuity plans among suppliers), to complement existing parameters such as cost and quality
- deployment of supply chain visibility tools that provide transparency into capacity constraints at first-, second- and third-tier suppliers
- increased use of tools and technologies to develop predictive models for proactive scheduling and dynamic planning that account for uncertainties and risks.

In addition to rethinking their supply chains, management teams will also need to re-examine their approach to project delivery and maintenance. COVID-19 led to the closure of construction sites around the world as employee safety plans were activated. Travel bans have had a direct impact on the availability of labour. The construction industry's workforce is particularly vulnerable to labour restrictions, given that most of the work must take place onsite. However, the disruption to onsite staff operations could also accelerate new types of project workflows, such as modular and offsite production.

Taking construction offsite or into a manufacturing environment opens the door to more standardised designs, streamlined processes and automated production techniques that incorporate technologies such as advanced robotics and the Internet of Things (IoT). And advocates say that modular construction is faster, safer and more efficient than onsite building and assembly.⁴



Technology adoption

As PwC thought leadership has shown, infrastructure is relatively underinvested in advanced technologies compared to other capital-intensive industries.⁵ In the current environment, pressure from reductions in capacity and rising costs may encourage asset owners and project managers to accelerate the adoption of technologies such as artificial intelligence and robotics. There is also an opportunity to reduce maintenance capital expenses using technologies such as intelligent drones.⁶ These drones reduce the need for onsite workers, thus increasing safety, and they can dramatically improve preventive maintenance — inspecting and scoping work faster than existing methods and providing more detailed information about required repairs.

More broadly, the shift to remote working arrangements across many industries has underlined the growing need for secure, resilient, cloud-based technologies and connective infrastructure.⁷ Growing usage of cloud technology will boost demand for data transmission and storage assets — including fibre networks, data and edge data centers, and telecommunications towers — that are already popular among infrastructure investors.⁸



Affordability

The industry already faces a significant shortfall in infrastructure spending globally, particularly in developing economies. Undoubtedly, the measures taken to shore up economies will have an impact on infrastructure investment, as spending earmarked for construction may now be channelled into social initiatives such as unemployment benefits and healthcare.

But there are also signs that some larger economies are considering spending on labour-intensive infrastructure projects as part of their stimulus efforts. These initiatives are likely to focus on ‘shovel-ready’ projects that can quickly boost economic output. The main challenge for the infrastructure sector may be identifying those projects that provide significant long-term contributors to economic livelihood — and address priorities that have surfaced through this pandemic, such as the need for greater digital connectivity, robust utility infrastructure and healthcare provision. The limited capacity for the construction industry to deliver such projects may be another challenge.

For projects financed through public–private partnerships (PPPs), demand-based contracts — typically used for assets such as airports and toll roads — are proving vulnerable to shocks, while those under an availability-based structure are exposed to reduced government budgets. The current crisis is likely to prompt a reassessment of investment risk and stress testing, as well as increased demand-side forecasting, planning (together with a move toward more conservative PPP deal structures) and risk allocation.

Risk aversion in the private sector will likely be high for the foreseeable future, and governments’ interventions to mitigate the disruptions arising from the crisis will have an impact on the risk perception of infrastructure going forward. Fiscal positions have deteriorated, but infrastructure needs have not. Narrowing the infrastructure gap just became even more challenging. The reality is the gap was unaffordable; too many commentators had focused on ‘financing’ for plugging the gap rather than how that financing was to be repaid. In an overtaxed and overborrowed world, affordability is key.



Sustainability

Some may view the pandemic's effects on emissions as the type of impact that climate change activists have been seeking for decades: closed factories and grounded airplanes reducing pollution levels and revealing landscapes previously assumed lost. Of course, the respite is temporary and arrived in an unsustainable manner, and it merely distracts from existing campaigns to find solutions for shifting to a cleaner economy. The climate consequences of the pandemic are not an environmental panacea. Greenhouse gases are still being emitted, carbon dioxide levels in the atmosphere are still at a record high and the planet is still in a race to limit climate change.

The transition to low-carbon, climate-resilient infrastructure assets remains a key aspect of those solutions. Estimates show that about 70% of the increase in future greenhouse gas emissions will come from infrastructure that is yet to be built. In an ideal world, any infrastructure-related stimulus should be focused on activities that reduce carbon consumption: the progression from fossil fuels to renewables; incentives for cleaner, greener construction methods; and the promotion of environmentally friendly modes of transport. In other words, recovery efforts can create an opportunity to advance the decarbonisation agenda.

That agenda also aligns well with the significant pools of capital increasingly allocated to investments with a positive environmental impact. In response to increased pressure from a range of stakeholders, many infrastructure investors are strengthening their environmental, social and governance (ESG) focus and want to invest in environmentally sustainable assets. In addition, several standards and frameworks have emerged to integrate climate-related factors into investment decisions and redirect capital to environmentally sustainable projects. As ESG reporting becomes more mainstream and policy pressure increases, it is reasonable to anticipate further demand for such assets in the future.

The pandemic and climate change are both global problems, and in responding to the former, there is an opportunity to build resilience for the latter.

In sum, although COVID-19 has put the infrastructure industry to the most severe of tests, the sector remains as essential as ever and will respond in line with underlying demand. By understanding how the pandemic has changed industry dynamics, leadership teams can position themselves to capitalise when the rebound comes.



Developments

in financing



The infrastructure funding challenge

The pressing global need for substantial infrastructure is widely recognised. For populations worldwide, upgraded or new infrastructure will be pivotal to the future availability of clean drinking water, housing and business space, lighting, sanitation, and other vital resources. As a result, the total global requirement for infrastructure investment is estimated at US\$3.9tn annually,⁹ with the greatest demands being in emerging markets.



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The challenge isn't just to fund the massive investment required. It's also necessary to provide infrastructure on an affordable and socially equitable basis.



Urbanisation, population growth and economic expansion — forces that are particularly powerful in developing countries — are making the need for new and updated infrastructure even more urgent. The urban population is expected to grow from 3.9bn today to around 6.3bn by 2050. The Asian Development Bank (ADB) estimates that some US\$1.7tn will have to be invested annually in infrastructure across Asia through 2030 if the region is to maintain its growth momentum, eradicate poverty and respond effectively to climate change.¹⁰ This is more than double the US\$750bn annual requirement announced in 2009. The gap between infrastructure capital demand and supply is not narrowing — it is widening.

Such investments are not optional: infrastructure is critical not only for meeting basic human needs, but also for supporting economic growth and maintaining quality of life. In 2018, the number of people living in informal settlements — which lack basic resources such as clean drinking water, sanitation and lighting

— rose to more than 1bn. Over 80% of affected people are located in three regions: Southeast Asia, sub-Saharan Africa, and Central and Southern Asia, according to the United Nations (UN).¹¹ The total global population of informal settlements is expected to reach a staggering 2bn by 2030 — meaning that about 25% of the projected global population will be without the infrastructure to meet their most basic requirements.¹² These figures underline the scale of the challenge.

The challenge isn't just to fund the massive investment required and target it at the right infrastructure projects. It's also necessary to provide the required infrastructure on an affordable, socially equitable and environmentally sustainable basis, and against the backdrop of climate change. These issues were formidable even before COVID-19 emerged. But the pandemic — and the pressure it will exert on the global economy — take the infrastructure finance and funding challenge into uncharted territory.

Why is there a gap between infrastructure capital demand and supply?

Although the terms *funding* and *financing* are often used interchangeably, they mean very different things. Understanding this difference is an important part of analysing and communicating the challenges to closing the infrastructure gap.

Financing represents the money borrowed and has the effect of time-shifting costs incurred. For example, a city borrows money to construct an infrastructure project and doesn't start to repay the loan for five years. In this case, the cost of the project has been time-shifted into the future through financing. However, financing doesn't set out how the funds to repay the loan will be earned.

Funding is the means by which a project's costs are repaid, regardless of the period to which these costs are time-shifted. For infrastructure, this generally

means identifying the long-term revenue stream necessary to repay the money initially invested, plus interest.

In light of the distinction between financing and funding, how do costs fit in? For the foreseeable future, governments will remain the largest payers, generating revenue for infrastructure costs through taxes, tolls and other user charges. Although users and customers will inevitably pay in the future to benefit from the services that infrastructure enables, governments will ultimately continue to fund and underwrite it. This makes closing the gap in less developed countries especially difficult, because their governments and citizens generally have fewer resources to contribute to infrastructure than do their more developed counterparts.

Some money is available in the form of grants, concessional loans and the like, but in terms of getting infrastructure development underway, governments cannot finance the needs alone. So multilateral development banks (MDBs), international financial institutions (IFIs) and other sources of private finance will all continue to play an important role.

It is important, however, not to think of MDBs and IFIs as playing a substantial gap-filling role. Their direct finance, even if stretched, is dwarfed by the estimated infrastructure gap.¹³ The focus should be on how their resources can be used to draw in more resources. In developing economies in particular, MDBs are actively seeking to tap into private capital through mechanisms such as blended finance.¹⁴ This financing model seeks to remove bottlenecks by reducing risks and guaranteeing investments via instruments such as guarantees or flexible (concessional) debt or equity. MDBs can also provide support by improving the local investment climate and offering specialised advisory services or local expertise to bridge knowledge gaps on transactions. Blended finance isn't intended to subsidise private investors unnecessarily. It is implemented by MDBs and IFIs in specific circumstances to encourage investment by facilitating risk-taking to an acceptable level.



Yet despite these ongoing efforts, not enough of the potential investment is finding its way to developing countries. The World Bank indicates that pension funds, sovereign wealth funds, mutual funds and other institutional investors make up only 0.67% of total global investment in developing countries.¹⁵

This low investment level is predominantly due to perceived risks around political instability, currency fluctuations, the degree to which earnings can be repatriated, rule of law and the ability of users to pay required tariffs. (For more insights into private sector infrastructure investment, see *Increasing private sector investment into sustainable city infrastructure*.¹⁶)

Furthermore, the volume of investment in projects early in their life cycles isn't enough to support the development of new infrastructure — especially when costs are often quoted in the trillions of dollars. Many greenfield opportunities arise in emerging markets, adding another perceived risk dimension. All of these factors help to explain why the gap between capital demand and supply isn't closing, and is even more pronounced in the initial stages of the life cycle of projects.

Various governments, donors and institutions have sought to help narrow the gap by providing funding for project preparation facilities (PPFs) — platforms that support activities early in a project's life cycle — and upstream support to create opportunities for project development and investment.

In general, private capital is reluctant to invest at the required scale in large greenfield developments, given the difficulties both in accurately budgeting development costs and timelines and in forecasting future revenues in the absence of an operating history. These concerns are heightened by well-publicised examples of greenfield construction projects experiencing difficulties. For example, construction of the metro system in Salvador, Brazil, began in 2000, but it took more than a dozen years for the first passengers to ride it.

The aversion to early-stage projects in developing countries — despite the growing need for infrastructure investment in those areas — has resulted in a pool of inaccessible capital building up, as private investors grapple to target a limited group of assets perceived to be safer. At the same time, banks continue to face pressures on long-term lending, causing them to lend over shorter terms or for larger lump-sum repayments.

However, the growing involvement of institutional investors has been a positive development. The period since the 2008 global financial crisis has seen a significant increase in institutional lenders such as pension funds and insurance companies putting debt and equity into infrastructure projects. In some cases, they have provided debt to enable operational infrastructure projects to refinance and/or take out bank lending; increasingly, they have also shown remarkable flexibility in lending to projects entering or already in the construction phase. These institutional investors are logical holders of infrastructure debt, because it matches with their long-term liabilities.

Other forces shaping the landscape

A further vital factor helping to shape the financing landscape is the global shift from a 'brown' to a 'green' economy. The UN's Sustainable Development Goals (SDGs) are supporting this transition, and infrastructure appears both as an explicit goal and as an implicit means to implement and achieve other SDGs. The financial costs of meeting the SDGs have been estimated at US\$5tn to US\$7tn annually through 2030, with about half going to developing economies.

An expanding base of stakeholders — including investors and civil society generally — are now looking to develop and benefit from more energy-efficient and environmentally sustainable built assets. This demand is coupled with a rise in activists targeting companies and high-profile individuals linked to the fossil fuel industries and others generating substantial carbon emissions.

These developments are driving pools of capital to be directed to those investments with a positive impact profile, with ESG considerations becoming more embedded in the risk assessment, selection, management and reporting processes for a growing proportion of investors, in both infrastructure and other assets. According to the latest biennial *Global Sustainable Investment Review* from the Global

Sustainable Investment Alliance (GSIA), released in mid-2019, global sustainable, responsible and impact (SRI) investments stood at US\$30.7tn at the start of 2018, a rise of 34% from 2016.¹⁷ Europe accounted for the largest pool, with US\$14.1tn of SRI assets under management, followed by the US, with US\$12tn. Furthermore, the Climate Bonds Initiative has estimated that the total issuance of green bonds — debt instruments designed to raise capital specifically for environmentally friendly projects — hit US\$250bn in 2019, up from US\$3.5bn in 2012.¹⁸

The shift in public opinion and market sentiment towards sustainable assets is also driving corporations, banks and other investors to assess their existing portfolios and assets that threaten to add to global warming. According to the *Financial Times*, around US\$900bn — one-third of the current value of big oil and gas companies — would disappear if governments more aggressively restricted activities leading to the rise in global temperatures.¹⁹ Stranded-asset risk will be an increasing focus going forwards.

As ESG and climate-related standards and frameworks continue to gain ground, there theoretically will be no shortage of financing for sustainable infrastructure. However, scaling this investment up will continue to require government intervention to make the business models work and attract investment, whether through subsidies, tax breaks or other mechanisms. These

measures will have to be supported by a step change in public policy and private investment decisions to make climate resilience an automatic and critical investment consideration.

Moreover, new technologies will be a big part of the solution to today's infrastructure challenges, improving transparency and efficiency while also creating new, often more sustainable, business models — from design through to operation and decommissioning. Indeed, new technologies are already generating new businesses and with them new opportunities, challenges, cash flows and services for governments. For example, some municipal streetlights are now being fitted with sensors, wireless transmitters, electric vehicle charging stations, 5G transmitters and other digital technologies.

However, as with every other industry it touches, technology will be a disruptive force for infrastructure. Ever-shorter technology lifespans sit uncomfortably in long-term, inflexible infrastructure contracts. And as the adoption of new technology increases, investors will feel more comfortable about projects that leverage it for the public good. This suggests that shorter-term, more flexible contracts and financing will be required — both to respond to the changes in expectations and demand and to take advantage of the opportunities that technology opens up.

The challenges of a new financing model to build a new world

What can be done today to meet tomorrow's need for infrastructure financing? In simple terms, we need to help direct more private finance into infrastructure, particularly in emerging markets. We need to better prepare projects. And we need to de-risk investments, using a range of financing mechanisms.

Especially when projects are in the pre-construction phase, the most effective way to attract private capital may be to increase the emphasis on mechanisms such as blended finance,²⁰ thereby attracting outcome-focused and multilateral and philanthropic sources of development capital and/or funding. The issue boils down to the allocation of risk among different stakeholders, including taxpayers, users, financiers, insurers and the like. If these various stakeholders are all involved in a project, allocating risk among them will require clarifying the related complexities and getting each party's objectives — for example, focused more on development or commercial returns — properly aligned.

This latter point was demonstrated recently as measures to contain the COVID-19 pandemic were enforced. Projects financed as PPPs with demand-based contracts — such as airports and toll roads — suffered dramatic drops in passenger volumes, proving them to be vulnerable to external shocks. It is too early to know the long-term impact of COVID-19, but the crisis is likely to prompt a reassessment of investment risk and a shift to more conservative PPP deal structures that mitigate some of the potential risk from macro-economic conditions (for example, risk-sharing components and guarantees). The crisis also raises longer-term questions about the business models for those assets most severely hit, such as airports.

MDBs and IFIs are already playing an important role in encouraging more private investment, particularly for emerging economies. Building on that progress will require well-established support around the enabling environment — both for the general investment climate and in specific infrastructure sectors — as well as the use of initiatives such as project preparation facilities.



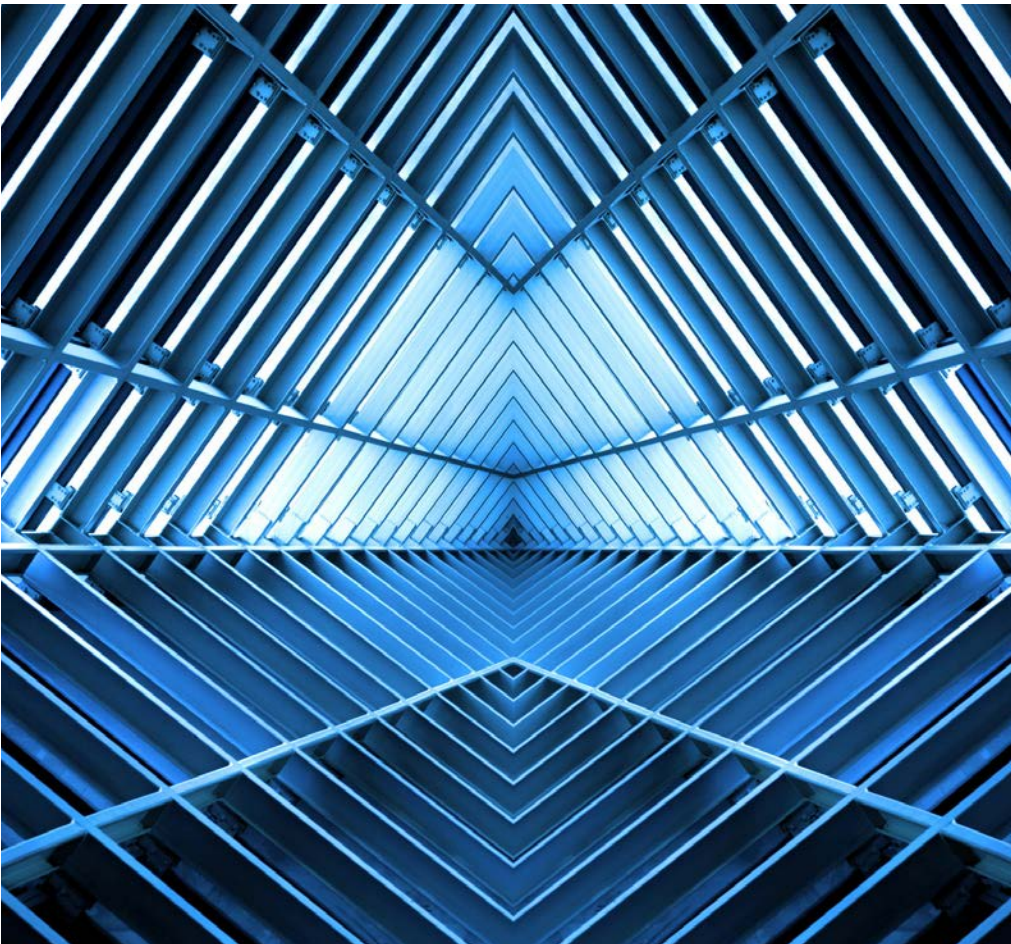


Ultimately, governments and taxpayers in the countries in which the projects are being built are going to bear the majority of the burden.

Looking across the current global environment for infrastructure financing, it's clear that the biggest challenge isn't the *availability* of funds. Instead, the challenge lies in mobilising those funds more effectively: building a pipeline of feasible projects and creating the structures, incentives and confidence levels needed to convince private capital to invest.

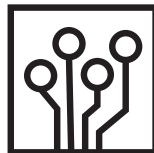
The MDBs alone don't have the balance sheets to be the risk takers of last resort in the volumes needed to close the gap. Ultimately, governments and taxpayers in the countries in which the projects are being built are going to bear the majority of this burden. Given affordability constraints, particularly in emerging markets, there is a strong possibility the gap will never close. In that case, the aspiration should be to close it as much as possible.

However, as the sheer diversity of forces and pressures underlines, money alone won't solve the problem. To narrow the gap between funding availability and need — between the risk appetite of investors and the places where investment is most urgently required — we'll need governments, MDBs and investors to continue to work together and develop innovative ways to finance infrastructure.



Developments

in technology



Technology's implications for infrastructure

Technology is revolutionising virtually every aspect of infrastructure. New developments span the entire industry, but three segments — power, ground-based urban transportation and air mobility — best illustrate the scope of the changes underway.

Power

In the power sector, growing energy demand has combined with environmental concerns, rising power prices and regulatory pressures to fuel the adoption of emerging technologies, such as renewable power, distributed generation, smart grids and battery storage. Almost three-quarters of new global electricity generation capacity built in 2019 used renewable energy sources such as solar and wind, an all-time record.²¹

Power companies are also using other technologies to improve resilience in a more decentralised market, reduce the frequency of outages and connect to consumers. For instance, battery storage can smooth variations in power, overcoming the intermittent nature of renewable sources. GlobalData estimates that the worldwide battery storage market will more than double between 2018 and 2023, growing from US\$6.1bn to US\$13.1bn.²² At the distribution level, sensors and associated data analytics systems are now making it possible to predict failures and carry out remote maintenance, and are also improving oversight of grid conditions, allowing the physical capacity of the network to be increased.

Among customers, industrial power users are applying the IoT to increase their operational efficiency and better manage the performance of their equipment. Residential consumers can now use smart meters to reduce consumption.

Collectively, this technological transformation is challenging the business models of utilities companies. To compete effectively in a more decentralised and disaggregated marketplace, these firms are now having to invest in new types of services, such as grid management and home energy services.

Urban transportation

Urban transportation is another area experiencing technological disruption. The majority of cities have a limited physical infrastructure capacity and are spatially constrained. While trying to meet the demands of increasing urbanisation, cities are also struggling to reduce road congestion and make mobility more affordable, efficient and environmentally friendly.

One critical goal of city planners is to shift away from privately owned, gasoline-powered cars, which are notoriously inefficient, and towards shared autonomous vehicles (AVs) and electric vehicles (EVs), such as robo-taxis and shuttles.²³ EV sales reached another record level globally in 2019, yet they still represent only a fraction of the overall light vehicle market. And bigger changes are needed to increase adoption rates, including wider availability of charging infrastructure and customer incentives to offset the higher upfront costs of buying an EV. In China, for example, the government's clear electric car strategy includes subsidies and fewer safety regulations, meaning that electric cars cost 43% less than the market average.²⁴



At the same time, citizens' expectations about how they can move around their environment are changing. From micromobility options such as dockless bikes and scooters to ride-sharing options like Uber, the world of mobility — long dominated by car ownership — is changing fast. Smart mobility, in its optimal form, could link together a journey planned by smartphone that might span rail and road, connecting to last-mile personal mobility options such as e-bikes or scooters. Even trips that span multiple cities, with data and money crossing borders and involving multiple organisations, would be accessible to users through a single interface. Capabilities such as these would require the connectivity of physical infrastructure (rails and roads) to operational technology that generates the data (sensors and payment systems), digital infrastructure (wi-fi and mobile connectivity) to carry that data, and finally IT assets to aggregate and analyse that data.

London is one of many cities worldwide looking to meet some of these new mobility expectations. It has introduced several measures, including congestion charging for non-EV traffic, dedicated cycle lanes, bike-sharing infrastructure, upgrades to bus fleets to include better traffic information systems, and EV charging points for electric cars and buses. Another crucial element in London's mobility efforts has been the decision by the city's transportation authority to

open up its (anonymised) customer data to private software developers, facilitating the development of user-friendly mobility apps.

As with power and utilities companies, original equipment manufacturers (OEMs) and their suppliers in the automotive industry are navigating a changing business landscape — one in which new entrants such as tech companies and venture capital-backed start-ups are gaining share. The sheer volume of investment required is driving an increasing number of partnerships and acquisition offers as companies strive to stay ahead of their competitors.

Air mobility

Looking forwards, limitations on ground capacity mean mobility will encompass more and more airborne options, such as flying taxis. The idea may sound futuristic, but air mobility solutions are becoming more feasible due to advances in battery technologies and communication systems.

Tests are underway by organisations such as Uber Air and German firms Lilium and Volocopter. European aerospace company Airbus is also working with the French Civil Aviation Authority and Aéroports de Paris to implement piloted flying taxis between airports and sporting venues at the Paris 2024 Olympics.²⁵ Making the leap from testing prototypes to operating vehicles

on a commercial scale will require more work on cost, noise and safety; for example, air traffic management has to be able to safely handle a much busier urban airspace. But real progress is underway, and regulators are beginning to approve limited applications for autonomous airborne vehicles.

In Switzerland, for instance, lab samples are being flown between local hospitals by drone. Meanwhile, in Iceland, drones are delivering parcels from online retailers to customers, and further progress is expected in the case of electric vertical takeoff and landing crafts (eVTOLs). Developments such as these have made air mobility a focus of attention for private equity houses and private companies, and manufacturers are increasingly optimistic about its future. By 2025, Lilium hopes to offer a trip from JFK Airport in Queens, New York, to Midtown Manhattan for around US\$70. By road, the journey takes about an hour (depending on traffic), but by air it would take just five minutes.

The hard infrastructure required to integrate and facilitate these technologies is not currently in place at scale. For example, key questions remain about how and where to build ubiquitous and reliable EV charging networks, how to provide connectivity and parking for autonomous vehicles or landing pads for flying taxis, and how electricity can be supplied reliably when a higher percentage of it is being produced from renewables.

The repurposing of existing infrastructure, such as car parks, creates another issue. Will they become charging stations for EVs and/or drop-in points for AVs? How will the business models for petrol stations look in the future? Amid such uncertainties, it's clear that adapting to the pace of innovation and capturing its full benefits will require a new, less fragmented ecosystem that includes alliances between businesses, public and private infrastructure stakeholders, and communities. At the same time, the assets themselves — both software and hardware — will need to be scalable and upgradable, with the flexibility to adapt to evolving needs and future technology capabilities.

Tech-enabled changes in the delivery of capital projects

The construction industry historically has lagged behind other industries in embracing digital technology to improve operations and realise efficiencies. However, as recent PwC thought leadership has highlighted, top-performing organisations are now deploying tools to increase productivity, improve efficiency and safety, and reduce costs on major capital projects.²⁶

Key technologies for achieving these goals are growing rapidly in sophistication.²⁷ California-based Skycatch is building drones that will use machine learning to generate a 3D model of a construction site, calculate the area and the volume of earth to be moved, plan the

work, and even guide autonomous onsite construction vehicles. Additionally, drones are performing diagnostic functions such as inspecting difficult-to-access locations, including pipelines and sub-level infrastructure.

Technology is also improving the efficiency of project construction and delivery, for example, by using robotics to automate construction processes. Using the vast increase in bandwidth offered by 5G networks, advanced sensors can now be placed on transport infrastructure to collect real-time data that enables the creation of digital twins for projects underway. One successful application is the work by UK-based Sensat on the country's HS2 high-speed rail link. Sensat is modelling the route of the proposed railway line to help monitor the project's progress and ensure that workflows are efficient.



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In parallel with these advances, the construction industry is starting to adopt data-driven technologies such as Building Information Modelling (BIM) and full-site data analysis to make budgeting and scheduling more accurate.²⁸ Wearable devices for workers can collect data on worksites, creating huge opportunities to improve safety. One Australian construction company now provides its workers with smart helmets that monitor their temperature for heatstroke, keeping them healthier and reducing sick days. Other wearables applications include collision avoidance systems and smarter management of site access rights.

Data can also generate major benefits when construction is complete and projects become operational. Predictive analytics can generate forwards-looking insights about environmental conditions and structural performance to better anticipate maintenance requirements, thus reducing costs. Also, insights about how assets perform across their life cycle could unlock new and different service models for contractors and help stakeholders invest in projects with a greater degree of confidence.

In addition, sophisticated digital infrastructure will become more important to the functioning of society as a whole, leading to ongoing investments for the foreseeable future. For example, high-speed communications infrastructure such as 5G is instrumental in the shift to more connected living, because without it the data simply won't flow. In many countries, the speed and extent of wireless network

coverage — together with the protocols governing wireless use — are major limitations on the ability to capitalise on data.

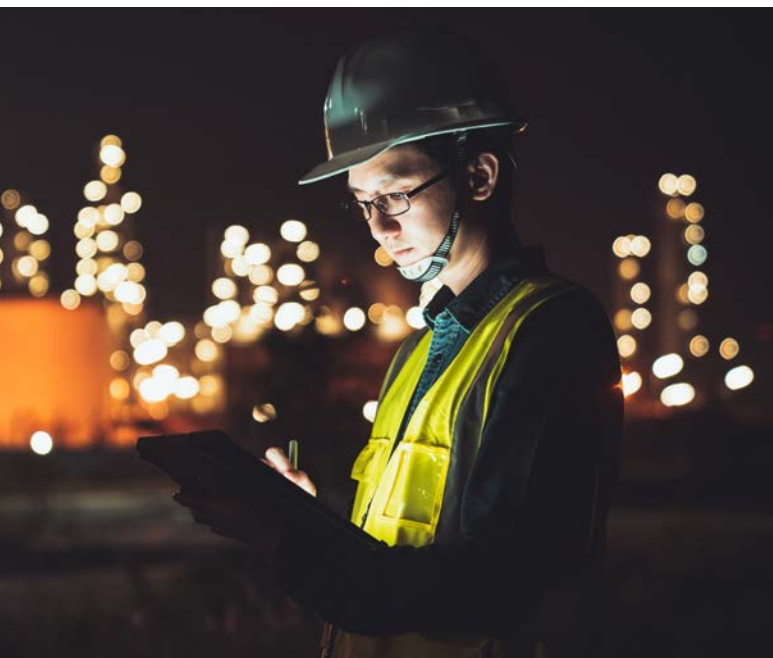
As dependency on IoT-enabled services and cloud computing grows, we will continue to see increases in the roll-out of enabling infrastructure such as data centres. There are also important interdependencies at play. For example, the IoT relies heavily on the reduced latency brought by 5G and edge computing (essentially a distributed collection of micro data centres that process or store critical records locally).

The implications for infrastructure projects and stakeholders

As new technologies become more critical for the successful delivery of infrastructure assets and their subsequent operation, there will be profound implications for various stakeholders in at least three areas.

New business and financing models

Consider the ongoing outfitting of streetlights with sensors, wireless transmitters, EV charging stations, 5G transmitters, security cameras and other digital technologies, all of which open up new sources of revenue and additional means of financing projects. Though these are positive developments, the growing role of technological innovation is also making asset



life cycles less predictable (causing a ripple effect along supply chains affecting service providers). And current contract structures, which last for decades and are highly rigid, are impeding the application of novel technology. The disparity between technology cycles and asset timelines will have significant consequences for contractors and financing organisations, which will need shorter-term contracts and a more flexible approach to financing. Similarly, projects will require open-ended approaches to create business cases that allow and encourage innovation.

Legacy assets

The industry will need to address the way that evolving technology makes some legacy assets obsolete. For investors seeking long-term, predictable revenues, infrastructure's need for more adaptable and fluid business cases is problematic. If investors target, say, battery storage, they need to assess whether the underlying technology is likely to change in the next several years and make existing systems obsolete.

The additional risk of obsolescence means that companies and investors need the capabilities and expertise to determine which technology trends will dominate specific asset types. They must also consider the management of legacy investments — and the related repayment obligations — when new technologies are introduced that threaten to undermine

the original investment assumptions by reducing demand for the asset (or even stimulating demand for new services based on it). Because technology forecasting is becoming so critical, many infrastructure businesses are investing in or acquiring technology start-ups to bring this expertise in-house.

Cybersecurity and data privacy risks

Infrastructure assets, especially critical infrastructure such as power plants, have always been vulnerable to physical damage. Now, these assets are controlled by cloud-based technologies, which introduce the risk of cyber threats. In the transport sector, North Korea reportedly tried to hack South Korea's rail transit system, and criminals have used ransomware to shut down metro operations in Germany and San Francisco. In energy, Ukraine's power grid was the target of a cyberattack in 2015 that left nearly a quarter of a million people without electricity. And in PwC's latest Global CEO Survey, CEOs from transport and power companies ranked cyber risk as a top concern.²⁹

At the same time, data privacy and ownership is a growing issue, particularly in relation to the development of smart cities, in which many of the digital partners are commercial technology companies and consumers are concerned about balancing private profit and the public good. It's already become a key issue for projects such as the Sidewalk Labs smart city



New and emerging technologies will be a huge part of the solution to today's infrastructure challenges.

development in Toronto. Overall, it's clear that cyber risk should be placed front and centre when cities consider the digitisation of operational infrastructure, to help create a layer of resilience that will be crucial in delivering a safe, connected infrastructure environment in the future.

Alignment among stakeholders

A number of other elements must also be in place if future projects are to realise the full benefits technology can offer. Given the need to address and reconcile a wide variety of stakeholder interests — including those of infrastructure planners, users, developers and investors — careful coordination and balancing of objectives will be essential. Also, the ability to drive large-scale innovation in projects will depend on conducive regulation, political will and clear legal frameworks. Such is the pace of technological change, however, that legislators and regulators are struggling to keep up. And public entities will need to reassess their procurement processes to integrate technology, determine how its benefits will be captured and measured, and encourage the innovation required to increase the pace of technological progress in infrastructure.



Reinvention through disruption

New and emerging technologies will be a huge part of the solution to today's infrastructure challenges — improving transparency and efficiency; facilitating the transition to low-carbon, climate-resilient assets; and unlocking more sustainable business models. But, as in every industry, technology is a disruptive force, displacing traditional ways of planning, financing, delivering and maintaining infrastructure.

Incorporating technology into infrastructure projects will require a step change in policy focus, new financing solutions at both the consumer and portfolio levels, and more research and development to push faster technological innovation. These needs are now on the agenda of many infrastructure stakeholders. Over the next few years, we'll see the increased focus on innovation in infrastructure bear fruit. And populations across the world will experience the benefits.

Infrastructure technology in emerging economies

Even as developed economies capture the benefits of infrastructure technology, emerging countries have struggled to realise these same advantages, largely due to weak digital foundations and poor adoption rates. This is a missed opportunity, especially because the savings generated through technology could determine whether a project goes forwards or not.

Of course, working in regions with less advanced technology can add complexity to infrastructure projects. Yet some countries with less legacy infrastructure and leaner, less bureaucratic governments may be better positioned than more developed countries to take advantage of technology innovation and accelerate their digitisation journey. In that way, they can leapfrog over more advanced countries.

If they are to do so, procurement processes must be transparent and create the right incentives for the application of new technologies. Governments must also develop supportive regulations to manage use. And, critically, governments can seek incremental benefits rather than trying to completely disrupt established processes. For many countries working to build core power, transport, water and urban infrastructure, the reality is that the traditional models of infrastructure financing — large capital investments repaid over long periods of time — are still attractive.

Finally, governments should stay abreast of what emerging market pioneers are doing. For example, India and some countries in the Middle East are already gaining a foothold in 5G and smart cities. These leaders will play an important role in setting the pace and direction for other emerging economies seeking to capitalise on such technologies in the future.

Developments in sustainability



Two critical trends: Urbanisation and climate change

In developed and developing countries around the world, infrastructure delivery is facing two key challenges. Both are integrally connected to the global issue of sustainability, and both are likely to have a disproportionate impact on emerging economies.

The first critical trend is urbanisation. The global urban population, currently around 3.9bn people, is expected to grow to around 6.3bn by 2050 and comprise 70% of the total projected global population in that year. This growth in city dwellers is fastest in a handful of emerging markets and developing economies — namely India, China and Nigeria — which will collectively contribute more than 35% of overall growth in the urban population between 2018 and 2050.³⁰

Against this background, it will be vital for urban planning, construction, and water and waste management projects to address the needs of burgeoning city populations. Energy provision will need to be sustainable to reflect ongoing changes in the ways people live and move around. Urbanisation is already putting transport systems under intensifying pressure: new road and rail systems are difficult to construct in environments that are already built up.

The second challenge is from climate change, a problem that cities exacerbate. According to UN Habitat, cities consume 78% of the world's energy and produce more than 60% of greenhouse gas emissions.³¹ Infrastructure construction and its use, such as power plants, buildings and transport, are large contributors to that figure.³² Additionally, 90% of urban areas are situated along coastlines, making them especially susceptible to the predicted rise in sea levels. Cities in emerging economies are particularly vulnerable, because they are usually characterised by rapidly swelling informal settlements that lack basic infrastructure and services,³³ which exposes their communities to the harshest impacts from changing climates, such as extreme weather events and flooding. Climate change-driven disasters accounted for about 91% of the 7,255 major disasters that occurred between 1998 and 2017.³⁴



Stricter emissions targets

Past trends suggest that infrastructure development will not keep up with demand — making it difficult for governments to deliver an adequate standard of living and meet modern-day expectations. Overlay the targets and commitments being set at a policy level, such as the UN's SDGs,³⁵ and the challenge escalates even further. The UK was the first major economy to legislate to reduce all greenhouse gas emissions to net zero by 2050. The EU has recently announced its own €100bn European Green Deal, setting out its ambition to make Europe the first climate-neutral continent, also by 2050.³⁶

Achieving these targets will demand a different approach to infrastructure planning in order to build low-carbon, climate-resilient and sustainable projects at scale.³⁷ It will also require accelerating the transition to more sustainable forms of power — an area where great progress is being made, but more needs to be done³⁸ — and a reimagining of transport, including 'smart mobility' in urban environments designed to ease congestion and smooth travel flows while also helping to reduce harmful emissions. In addition, older assets will need to be decommissioned or retrofitted to adapt to climate change. (See "The rise of stranded assets.")

The rise of stranded assets

Companies and investors are assessing their existing portfolios to identify any assets that threaten to intensify global warming. According to estimates by the Financial Times' Lex team, around US\$900bn — one-third of the current value of big oil and gas companies — would disappear if governments became more aggressive in their attempts to restrict the rise in global temperatures.³⁹ Although the risk of such 'stranded assets' is most naturally associated with the energy sector, other companies will be affected as well. For example, owners of assets such as petrol stations or car parks will need to consider how to repurpose or divest those assets. Stranded asset risk is set to become an increasing focus and consideration going forward.





Opportunities in emerging markets

The prospect of urbanisation and climate change brings huge challenges — and opportunities — for investment in sustainable infrastructure across all sectors. The International Monetary Fund (IMF) estimates that the spending required to meet the SDGs in 2030 amounts to US\$2.6tn — or 2.5% of the 2030 world GDP — in 121 emerging-market economies and low-income developing countries.⁴⁰

According to the World Bank, new climate-smart infrastructure alone could cost low- and middle-income countries anywhere between 2% (US\$640bn) and 8% (US\$2.7tn) of GDP per year through 2030. Emerging markets are expected to account for most of the projected doubling of infrastructure spending by 2050,⁴¹ primarily through greenfield projects. A recent International Finance Corporation (IFC) report concluded that cities in emerging markets have the potential to attract more than US\$3.1tn in climate-related investments in renewable energy, public transportation, waste and water by 2030.⁴² Stakeholders in emerging markets have a unique opportunity to grow their economies and build infrastructure in more sustainable ways by learning from the climate impacts of cities in more developed jurisdictions.

Designing for the life cycle of an asset

At the same time, assets in developed markets may need to be adapted based on changing needs among users. Consider car parks. In the UK, the average car is in use only 4% of the time.⁴³ Increasing adoption of more environmentally friendly electric vehicles such as cars, vans and bikes means that in the medium term, there is a growing need to adapt car parks into charging stations. In the longer term, car parks could become part of the electricity grid, helping to store energy more evenly and removing supply bottlenecks. Similarly, a rise in autonomous vehicles could trigger a move towards suburban or out-of-town car parks. Designing and building infrastructure for flexible uses during its life cycle will be key.

A similar principle is at play in the power sector. The move to cleaner infrastructure such as EVs and the electrification of transport is not itself a fully carbon-positive story. Demand for battery metals — cobalt and nickel — continues to grow rapidly and could face a supply crunch by the mid-2020s. Similarly, global wind technologies are expected to require an average of 450,000 tonnes of copper per annum out to 2022, increasing to 600,000 tonnes per annum out to 2028.⁴⁴ It is undeniable that extracting and refining metal also produces carbon.

As demand for renewable power increases, structures will need to be designed in a way that maximises lifetime value while preserving the flexibility for reuse along the entire life cycle of materials. Wind turbine blades are just one example of a problematic early design. The first generation of blades was installed in the 1990s, and many are reaching the end of their 25-year working life expectancy.⁴⁵ Disposing of the blades in an environmentally friendly way is a growing problem. Some are being converted into injectable plastics or highly waterproof boards that can be used in construction. However, many are simply being buried in landfills.

A more sustainable, circular-economy approach for all infrastructure assets will require a shift in procurement strategies, challenging the construction industry to consider the full environmental impact of the materials used,⁴⁶ the finished asset, operations across its life cycle and ultimately its decommissioning.

Effective corporate-level measurement will also be required. Sustainability as a concept works only if it can be measured and checked. Increasingly, the impact of a business on the environment and broader society is as important as its financial return. Despite the growing focus and desire of stakeholders to consider environmental and sustainability impacts, many current business models are not equipped to quantify and monetise this component, meaning it is removed from traditional ROI decisions. More comprehensive frameworks are needed to determine the various ways that a company or asset generates, or potentially destroys, value, in both the short and long term. This will help decision makers to consider the net impact of their actions, beyond financial results.⁴⁷ (See “A metro project applies advanced metrics.”)



A metro project applies advanced metrics

One example of a project applying a more comprehensive approach to quantifying its environmental impact is the Stockholm metro extension. The US\$3.35bn project, currently underway and slotted for completion by 2026, comprises 20 kilometres of new track and 11 new train stations. To reduce the carbon footprint of the stations' construction, the project team first calculated the cost and the carbon footprint for a model station. Concrete and steel were the main contributors to the carbon footprint. The team then identified measures to reduce the amount of new material required, redesigning the station and replacing some design aspects with recycled steel and other materials. A second iteration of the process — a calculation followed by a redesign — reduced the carbon footprint even further. Ultimately, the team was able to reduce the overall carbon emissions of the project by 40%, along with a 30% reduction in costs.⁴⁸



Clearing the bottlenecks

What needs to happen for infrastructure to play its full potential role in reducing climate change? Companies need to broaden their criteria for procurement decisions. Rather than focusing on the lowest-cost option, companies need to apply a framework that considers the total economic, social, environmental and financial impact over the whole life of the asset. This is more difficult in developing countries, where affordability is the key consideration and infrastructure is badly needed to provide services to growing populations.

To date, the supply of bankable sustainable infrastructure projects has been inadequate and sub-scale, particularly in low- and middle-income countries. The process is hampered by the fact that future climate change is difficult to model or predict, bringing a degree of uncertainty to the lifespan of sustainable assets. Also, there are some types of climate-required assets that do not have an obvious revenue stream: for example, flood defence systems or carbon capture and storage schemes.

One positive development in this space is the growing base of stakeholders — including investors and governments — looking to develop and benefit from more energy-efficient and sustainably built assets. Increased shareholder activism and a focus on ESG considerations has pushed significant pools of capital

towards more sustainable projects, as climate change impacts are increasingly being recognised as a key risk for private investors.

As the ESG agenda gains momentum, several worldwide standards and frameworks have emerged to facilitate the integration of climate-related factors into investment decisions. These include the guidelines from the Task Force on Climate-related Financial Disclosures (TCFD) and the European Commission's recently announced sustainability taxonomy and disclosure regulations, which are designed to formalise investors' disclosure obligations, create positive carbon benchmarks and minimise the potential for 'greenwashing' in the market.

Theoretically, therefore, there is no shortage of finance for sustainable infrastructure. And though sustainable infrastructure can be more expensive than high-carbon equivalents, consequently offering a lower return (before subsidies and taxes like carbon credits), some solutions, such as wind farms (reduced build and therefore shorter payback periods compared to fossil fuel power plants), are now making commercial sense in addition to making environmental sense.

To clear the bottlenecks and increase the flow of this investment, MDBs are prioritising inclusive, resilient and sustainable technology-driven infrastructure. Working hand in hand with governments and the private sector, they are looking to strengthen policies, legislation and regulations, and creating a pipeline of bankable projects to boost sustainable infrastructure investments.

Several other measures will increase the flow of finance to sustainable infrastructure.⁴⁹ These include close cooperation and partnerships among the various participants — impact investors, sustainable businesses, governments, financial institutions and others — as well as improved access to markets (especially in developing economies). Also required are high-quality education and skills training; further involvement from international financial institutions; and smart public policy, including incentives and regulations supporting sustainable development.

Building a sustainable future

Ultimately, the global shift to sustainable infrastructure will require interventions and collaborative action from multiple participants. These include not just public-private cooperation and consolidated effort, but also new ways of measuring impacts and the development of innovative instruments geared to financing green infrastructure projects. Also important at a national and regional level will be factors such as regulatory frameworks, subsidies and tax regimes. These overlapping considerations mean the task of funding and building sustainable infrastructure is arguably one of the biggest and most complex challenges that the global financial and political system has ever faced. But it's a challenge that must be overcome.

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