

Capital Projects and Infrastructure

Australia's infrastructure innovation imperative



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Executive summary

For 30 years, Australia has been a global innovation leader in infrastructure planning, financing, and delivery. Today, the country faces new challenges as population growth, urbanisation, and technology disruptions create the need for a step-change in infrastructure prioritisation, design, and productivity.

Founded on three decades of innovation around the financing and delivery of major public infrastructure, Australia is among the most advanced economies globally in terms of effective collaboration between the public and private sectors to deliver transport, energy, and social infrastructure. It has also become a leader in private infrastructure investment as managed funds seek opportunities in this sector, fuelled by the introduction of compulsory superannuation arrangements. Infrastructure makes a major contribution to the Australian economy in terms of jobs, growth, and exports—the country spent some A\$1,177 (US\$906)¹ per capita on transport infrastructure in 2017, ranking second among OECD countries.

Nevertheless, challenges will intensify in the future—especially around the country's ability to meet infrastructure demand. Australia's population is projected to grow to 40.6 million in 2050,² driven by growth in the country's two major cities: Sydney and Melbourne are expanding annually at 1.8 percent and 2.5 percent respectively.³ This rapid population increase means Australia faces a substantial infrastructure gap: the McKinsey Global Institute (MGI) estimates the shortfall between current infrastructure investment levels and needs (2017–35) to be 1 percent of GDP.⁴ To try to meet the demands of this rapid population growth in its urban centres, Australia is investing in transport, utilities, and social infrastructure at an unprecedented scale (Exhibit 1)—aggregate investment in projects greater than A\$50 million has climbed from A\$26 billion in 2016 to an estimated A\$77 billion in 2020.

Today, however, additional challenges are adding further complexity to the historical issues of delivering major projects on budget, an expanding infrastructure funding gap, and the sheer scale, pace, and inherent complexity of the infrastructure program. These include technology-led disruptions around the future of mobility, a clear need to reassess traditional commercial models, stagnating productivity, expected skill shortages, and the impact of major concurrent projects on city residents and communities. In the face of such emerging disruptions, one thing is clear: the strengths that have propelled Australia to a leadership position in infrastructure planning, design, and delivery will not be sufficient to underpin future success.

¹ 2017 average AUD to USD conversion.

² Population Projections, Australia, 2017 (base)—2066, *Australian Bureau of Statistics*, abs.gov.au.

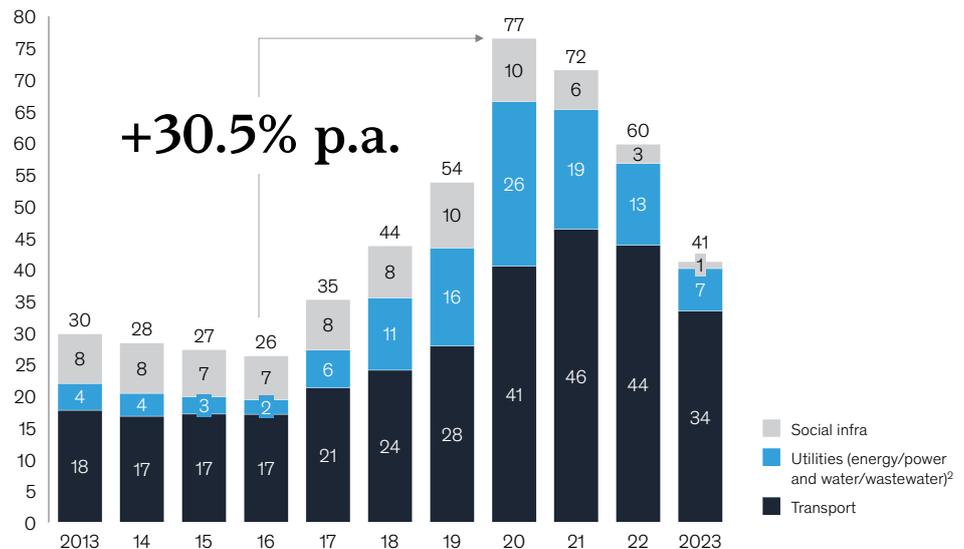
³ ABC news.com, March 29 2019, <https://www.news.com.au/finance/economy/australian-economy/sydney-is-shedding-established-residents-while-darwin-is-shedding-people-full-stop/news-story/4935683a798f5a5216b023fd8e610dc2>; and Australia Bureau of Statistics on population growth, <https://www.abs.gov.au/ausstats/abs@.nsf/latestProducts/3218.0Media%20Release12017-18>.

⁴ Bridging Infrastructure Gaps, Has the World Made Progress?, *McKinsey Global Institute*, October 2017, McKinsey.com.

Australia's infrastructure investment has grown at over 30 percent a year.

Preliminary High Level Estimate

Infrastructure spend per year based a McKinsey IPAT³ data of projects above A\$50m
A\$ Billions¹



¹ Converted from US\$ using April 2019 conversion rate.
² Excludes telecom infrastructure.
³ A bottom-up/zero-based approach to estimating spend of projects above A\$50m and excluding maintenance spend on capital assets
 SOURCE: IPAT probable spend data for projects value > A\$50m adjusted by the probability of projects to achieve completion and then divided over the duration of the project

There is an urgent imperative for infrastructure players in Australia to innovate across six dimensions:

- 1. Future proof new assets/investments.** Technology, digital, and data analytics are disrupting urban mobility, leading to uncertainty around future investments and opening up new possibilities for the way in which infrastructure assets are constructed and operated. New trends such as the uptake of electric and autonomous vehicles (implying increased road capacity, vehicle charging infrastructure, and curb modifications), smart-city technology, the future of work (which will affect travel patterns) and increased regulation and awareness of climate impact require infrastructure stakeholders to conceive an integrated vision of future mobility requirements for people and freight. This includes developing scenarios around the impact on transport infrastructure demand; translating these scenarios into future-proofed strategic prioritisation of capital and resources at a portfolio and project level (for example, by developing a point of view on the optimal share of investment between road and rail); identifying and developing new competencies and processes to achieve this future state; and creating a roadmap of initiatives and enabling actions (for example, changes to planning, creation of a “Future Mobility Hub”, and setting clear technology standards and safety requirements) to deliver the vision.
- 2. Rethink project selection and prioritisation.** The current processes by which projects are developed and assessed do not facilitate rapid needs-based prioritisation. Meeting future infrastructure needs will also mean being more “shovel-ready” by going to market with the right projects quicker. There are limitations to currently used metrics such as the benefit-cost ratio and net present value, and decisions can also suffer from inherent cognitive biases. Streamlining the business-case process can enable political decisions to be based on the best possible supporting evidence while providing timely analysis. Stakeholders can consider addressing these issues by focusing metrics on strategic objectives, applying debiasing techniques to improve decision making, developing capabilities to perform rapid strategic options analysis, and prioritising projects within specific investment categories.

3. **Drive value through design.** Increasingly complex projects expand the difficulties in preventing cost overruns and delays, highlighting the need for a more innovative approach at project design stage. Currently, decisions are often taken from a capital works perspective rather than a whole-of-life optimisation frame, while there can often be a lack of integrated perspective and ownership. Project owners are frustrated by traditional value-engineering approaches that tend to achieve only incremental benefits and take months or years. Moreover, projects can suffer from misaligned incentives, while regulations can hinder design innovation. Ways forward include combining an agile approach with design-to-value methodology, incorporating a rigorous framework for progressive, continuous, and stage-gated design, while also industrialising aspects of the design process.
4. **Innovate the commercial framework.** Aspects of the market's traditional risk-transfer model are leading to declining competition within public tenders for transport infrastructure projects, as the scale and risks associated with them—as well as the costs of bidding—climb. At the same time, MGI research⁵ suggests that contractors and suppliers consider contractual structures and incentives to be the principal hurdle to achieving better outcomes on projects—transaction complexity and regulatory burden add unnecessary cost and delays and prevent high productivity. In addition, the impact of multiple construction projects can be a significant issue for communities. To address these issues, stakeholders should consider streamlining the regulatory burden, increasing collaboration in contracting, reforming the tender process to promote competition, and bundling contracts to take advantage of economies of scale.
5. **Build industry capacity and capability.** There are shortages with regard to capability and capacity of suitably qualified and experienced personnel required to plan and deliver new infrastructure projects. We analysed three potential future scenarios and found that Australia could potentially need an additional 260 thousand to 385 thousand infrastructure construction workers over the coming years (Exhibit 2), if the projected pipeline materialises. There is an immediate need for more skilled workers, likely to be exacerbated by the coming ramp-up of mining production—potentially leading to labour inflation. Ways to bridge the capacity and capability gap going forward include managing both the demand for workers and their supply, including upskilling the current workforce, reframing the culture of the industry to retain more talent, and seeking ways to increase the talent pool and train the future workforce.
6. **Enhance productivity through technology.** Stagnation in construction productivity globally results in high costs for the taxpayer and significant project margin erosion for contractors. Ninety-eight percent of construction projects incur cost or schedule overruns, while lagging labour productivity is a key source of construction challenges. Improving on-site execution through well-executed practices such as lean construction techniques, performance management, effective project management supported by an active project management office (PMO) and control tower with efficient planning and project controls can help boost productivity by up to 10 percent—this is fundamental and needs to underpin all efforts in boosting productivity. However, we do not believe this will be enough and the sector will need technology to help it make the step change necessary to bridge its productivity gap. McKinsey research indicates that technology is the most promising lever for improving productivity, with approximately a 15 percent impact—for example, 47 percent of the work done in construction has automation potential.

⁵ McKinsey Global Institute Construction Productivity Insights Survey.

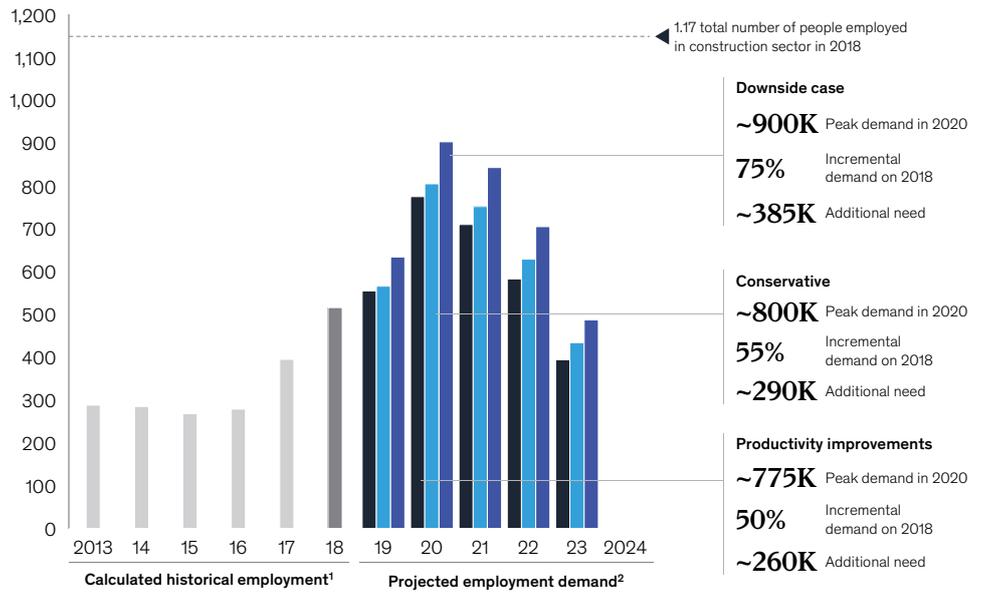
Australia faces significant demand for additional resources for infrastructure construction

Preliminary High Level Estimate

Estimated employment demand in infrastructure construction sector

Thousands

- 2018 actual productivity +10% productivity CAGR
- Last 5 years average productivity
- 2018 productivity



1. Based on assumed/calculated proportion of workers in the infrastructure sector, from total number of workers in construction sector as a whole, using historical spend split
 2. Based on assumed 2018 infrastructure sector number of employees and projected infra spend
 SOURCE: ABS, IPAT, McKinsey analysis

Drawing inspiration from infrastructure innovation and best practices globally (as well as from other sectors) can help Australia’s infrastructure sector achieve a step change in innovation—ensuring the next wave of infrastructure projects are successful in their outcomes. Here, we offer a number of critical takeaways for specific key stakeholder groups: government, investors, and contractors.

Government. As the ultimate funder of public infrastructure (accountable to residents for timely, effective, and affordable provision) and with responsibility for the policy, legal, and regulatory framework, government should consider how to:

- Publish an integrated vision for how technology will shape the way that people and freight move around a city—this will involve making purposeful choices around Australia’s future target state in relation to mobility, smart cities, and the implications of automation, capturing and articulating the implications of these trends and resulting choices for the allocation of capital.
- Identify and address the major policy enablers and barriers to the adoption of infrastructure innovations, while successfully managing the transition towards the future state enshrined in the vision. Government will need to set standards that mandate the adoption of technologies in the delivery of major infrastructure assets—for example, 5D BIM (building information modelling) where beneficial.
- Rethink the way projects are prioritised and selected by developing the capability to perform rapid options analysis, while reorienting formal business-case analysis to avoid simplifying projects to single (potentially misleading) metrics and focus on scenarios that take future disruptions into account.
- Develop the necessary internal capabilities to manage the portfolio of infrastructure megaprojects through their lifecycle. This is a non-delegable set of capabilities driven by government’s unique position as the integrator and ultimate owner of all risk and will include working with industry to conduct a collaborative design-to-value process, adopting an agile approach.

- Build industry capability, capacity, and competition by moving away from traditional contracting, risk transfer, and tendering models to create the conditions for new market entrants. Innovative practices include collaborative contracting and potentially setting up panels of qualified contractors to enable longer-term private-sector investment in capability development. Government should also consider developing a national infrastructure sector skills strategy.

Investors. In the face of disruptive trends creating huge uncertainty around investment cases, public and private-sector investors should consider how to:

- Apply design-to-value methodology using an agile approach.
- Actively assess the impact of disruptive trends on infrastructure demands and usage.
- Proactively consider investing in new asset classes created by technology.

Contractors. Currently confronting the prospect of a “profitless boom” caused by high transaction costs, staff churn, industry fragmentation, productivity stagnation, increased contractual and technical risk, and challenges in accessing skilled labour, contractors that can crack the productivity challenge and act as a thought partner to government will likely come out as winners. Aspects to consider include:

- Champion innovations to create a step-change in productivity by setting a technology vision, identify and quantify the technology “use cases” to unlock value, and commit to a roadmap that balances meaningful investment in core enablers (data analytics and multi-speed IT) with a phased approach that builds confidence—alongside an intensive focus on non-technology disciplines such as lean construction to ensure change is achieved in the front line.
- Develop capabilities to plan and deliver a portfolio of infrastructure megaprojects from conception and selection through to completion, while also incorporating the relevant process, technology, and business partnering skills (including agile and DTV) to drive enhanced performance and productivity.

Further details on the trends and levers discussed, along with stakeholder takeaways, can be found in the full report.

Context: Australia's infrastructure imperative

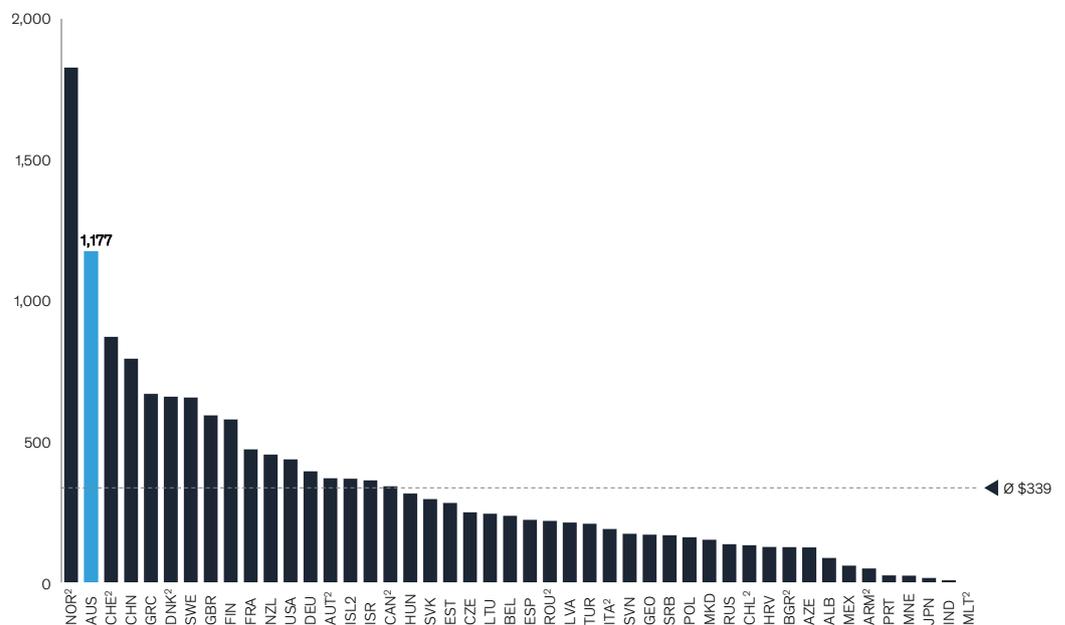
For 30 years, Australia has been a global innovation leader in infrastructure planning, financing, and delivery. Today, the country faces new challenges as population growth, urbanisation, and technology disruptions create the need for a step-change in infrastructure prioritisation, design, and productivity.

Today, Australia is an infrastructure leader. The country is among the most advanced economies globally in terms of effective collaboration between the public and private sectors to deliver transport, energy, and social infrastructure. Australia spent some A\$1,177 (US\$906⁶) per capita on transport infrastructure in 2017, ranking second among OECD countries (Exhibit 3).⁷ And infrastructure makes a major contribution to the Australian economy in terms of jobs, growth, and exports (Exhibit 4).

Exhibit 3

Australia ranks second among OECD countries for transport infrastructure spending on a per-capita basis.

2017 per capita spend on infrastructure (road, air, rail) A\$¹



¹ Converted from euros using August 2019 conversion rate
² 2016 data

SOURCE: OECD, World Bank

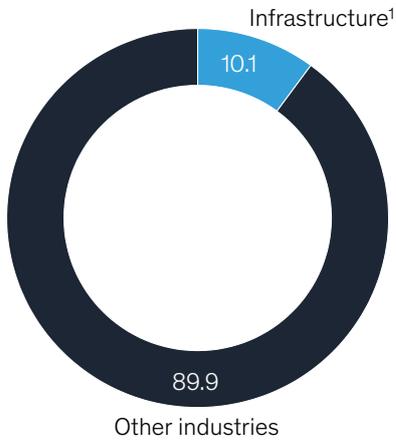
⁶ 2017 average AUD to USD conversion.

⁷ This relative per-capita spend can be influenced by the geographical footprint of cities, demand growth rate, and current infrastructure supply among other factors.

Infrastructure contributes 10 percent to the economy each year and employs 7 percent of the workforce.

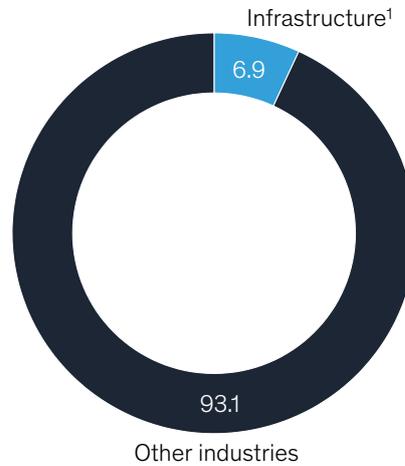
Gross value added to economy

At basic prices, 2017; Percent



Number of people employed

2017; Percent



¹ Includes transport, energy, telecommunications, and water.

SOURCE: Australian Infrastructure Statistics Yearbook 2018

This position of strength has been built upon three decades of innovation around the financing and delivery of major public infrastructure. In the early 1990s, Australia established a private infrastructure market, adopting public-private partnerships (PPPs) for road and airport programs. More recently, asset recycling in New South Wales (such as the sale of TransGrid in 2016) released vital funds for investment in projects such as Westconnex and Newcastle Light Rail. The PPP model has proved successful in bringing private capital and expertise to the delivery of public infrastructure (albeit that there were some early failures). Australia’s approach to infrastructure funding and delivery—including the hypothecated asset recycling model—has led to it being considered in other sophisticated economies, including the United States.

Meanwhile, Australia has become a leader in private infrastructure investment as managed funds seek opportunities in this sector, fuelled by the government’s introduction of compulsory superannuation arrangements. Australian investors and investment managers (for example, Macquarie Infrastructure and Real Assets, IFM Investors, AMP Capital) and developers (such as toll-road operator Transurban) are now major global players.

Rapid population growth, technology change, and disruptions will combine to challenge Australia's current infrastructure model

Challenges are set to intensify, however, especially around the country's ability to meet future infrastructure demand. Australia's population is projected to grow from 24.6 million in 2018 to 40.6 million in 2050,⁸ driven by growth in the country's two major cities, Sydney and Melbourne, are expanding annually at 1.8 percent and 2.5 percent respectively.⁹ To meet the demands of this rapid population growth in its urban centres, Australia is investing in transport infrastructure on an unprecedented scale, up from around A\$26 billion in 2016 to an estimated A\$75 billion in 2020 (Exhibit 5).

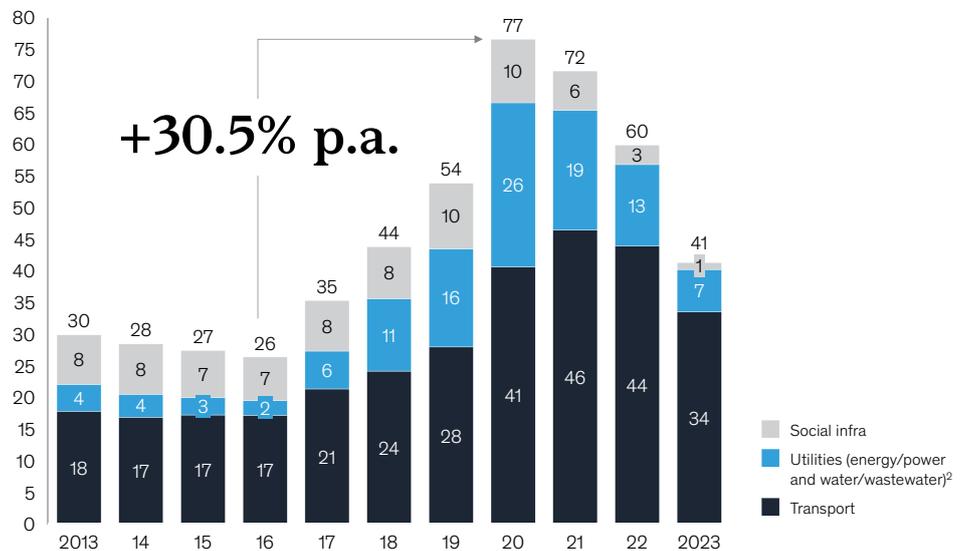
Yet, despite the current and planned pace and scale of infrastructure investment, rising population growth and the need to replace end-of-life assets mean Australia faces a substantial infrastructure gap—the McKinsey Global Institute (MGI) report, *Bridging infrastructure gaps, has the world made progress?* estimates the gap between Australia's current infrastructure investment levels and needs (2017–35) to be 1 percent of GDP,¹⁰ which implies a high-level estimated average spending gap of between A\$10 billion and A\$15 billion per year until 2035. Australia will need to close this gap while simultaneously addressing the traditional challenges associated with delivering major projects on budget, not least the sheer scale, pace, and inherent complexity of the infrastructure program. According to Grattan Institute, over the period 2000 to 2015/6, budget overruns on major Australian government transport projects totalled A\$28 billion.¹¹ Meanwhile, a number of new challenges have appeared over the horizon, adding further complexity to the issues just described.

Exhibit 5

Australia's infrastructure investment is growing at over 30 percent a year.

Preliminary High Level Estimate

Infrastructure spend per year based a McKinsey IPAT³ data of projects above A\$50m A\$ Billions¹



¹ Converted from US\$ using April 2019 conversion rate.

² Excludes telecom infrastructure.

³ A bottom-up/zero-based approach to estimating spend of projects above A\$50m and excluding maintenance spend on capital assets

SOURCE: IPAT probable spend data for projects value > A\$50m adjusted by the probability of projects to achieve completion and then divided over the duration of the project

⁸ Population Projections, Australia, 2017 (base)—2066, *Australian Bureau of Statistics*, abs.gov.au.

⁹ ABC news.com, March 29 2019, <https://www.news.com.au/finance/economy/australian-economy/sydney-is-shedding-established-residents-while-darwin-is-shedding-people-full-stop/news-story/4935683a798f5a5216b023fd8e610dc2>, and Australia Bureau of Statistics on population growth, <https://www.abs.gov.au/ausstats/abs@.nsf/latestProducts/3218.0Media%20Release12017-18>

¹⁰ *Bridging Infrastructure Gaps, Has the World Made Progress?*, *McKinsey Global Institute*, October 2017 – <https://www.mckinsey.com/~/media/mckinsey/industries/capital%20projects%20and%20infrastructure/our%20insights/bridging%20infrastructure%20gaps%20has%20the%20world%20made%20progress/bridging%20infrastructure%20gaps%20how%20has%20the%20world%20made%20progress%20v2/mgi-bridging-infrastructure-gaps-discussion-paper.ashx>

¹¹ Marion Terrill, Cost overruns in transport infrastructure, *Grattan Institute*, October 2016.

Australia needs to address a raft of emerging trends that threaten to disrupt the next wave of infrastructure megaprojects, and this brings a new set of challenges, specifically how to:

1. **Future proof new assets/investments**—technology, digital, and data analytics are disrupting urban mobility, leading to uncertainty around future major investments, as well as the way in which infrastructure assets are constructed and operated.
2. **Rethink project selection and prioritisation**—the current processes by which projects are developed and assessed do not facilitate rapid needs-based prioritisation, as well as the need to be more “shovel-ready” by going to market with the right projects quicker.
3. **Drive value through design**—increasingly complex projects expand the difficulties in preventing cost overruns and delays, highlighting the need for a more innovative approach at project design stage.
4. **Innovate the commercial framework**—aspects of the market’s traditional risk-transfer model are contributing to insufficient competition within tenders for public transport infrastructure projects, as the scale and risks associated with those projects, and the costs associated with bidding, climb.
5. **Build industry capacity and capability**—there are shortages with regard to capability and capacity of suitably qualified and experienced personnel required to plan and deliver new infrastructure projects.
6. **Enhance productivity through technology**—stagnation in construction productivity globally results in high costs for the taxpayer and significant project margin erosion for contractors, which in the most extreme circumstances have led to corporate failures (for example, Carillion). Technology presents the biggest opportunity to improve and drive productivity.

In the face of the disruption created by these emerging trends, one thing is clear: *the strengths that have propelled Australia to a leadership position in infrastructure planning, design, and delivery will not be sufficient to underpin its future success.*

Australia can innovate the way it plans and delivers infrastructure to meet future challenges

So how best to move forward? Drawing inspiration from infrastructure innovation and best practices globally (as well as from other sectors) can help Australia’s infrastructure sector achieve a step change in innovation—ensuring the next wave of infrastructure projects are successful in delivering the target social and economic outcomes.

In the following chapters, we discuss a series of levers around future proofing infrastructure investment, rethinking project selection and prioritisation, driving additional value through innovative approaches to project design, innovating the commercial framework, enhancing industry capacity and capability, and ways to harness technology to boost productivity.

In discussing these new approaches, this report recognises that public sector infrastructure owners (which account for the vast majority of infrastructure spending in Australia) face highly contextual challenges and constraints. These include:

- Co-dependence between the Commonwealth and state governments to fund and deliver infrastructure projects—this inevitably influences project selection and design.
- Procurement and probity rules may complicate or constrain governments’ ability to explore more radical procurement methods.
- Governments will be particularly sensitive to, and need to solve for, community concerns (for instance, around travel disruption) and political considerations.

We also note that there are a number of joint public and private sector initiatives, such as the Construction Industry Leadership Forum, set up to improve infrastructure industry outcomes. Hence, this report is intended as a contribution to, and by no means the final word on, Australia’s thinking on topics that we believe are important to the successful future delivery of the country’s infrastructure needs.

Chapter 1: Future proofing infrastructure investment

Rethinking the way we deliver infrastructure starts with assessing the potentially transformative impacts of technology and other infrastructure trends on demand.

A deeper understanding of the technology disruptions affecting infrastructure offers decision makers the opportunity to be better financial stewards by future proofing design, maximising asset utilisation, and responding appropriately to new digital asset classes. Multiple shifts, ranging from energy decentralisation to the Internet of Things (IoT), are likely to come together to create profound changes in mobility systems over the next 10 to 15 years. Therefore, today's infrastructure decisions need to be future proofed against, or at least adapted to, three trends that will reshape the future of infrastructure:

1. The **future of mobility**, with changes in behaviour, transport modes, and usage
2. The impact of **smart-city technology**, and the improved asset utilisation that will be possible from mining data for customer behaviour insights
3. The **future of work** driven by an increase in automation and remote working.

In addition to the trends above, climate change and associated increasingly onerous regulations, for example on congestion and air pollution, will continue to drive the need for sustainable transportation. Technology presents potential and disruptive solutions in the quest for sustainable mobility.

The impact of these three major trends need to be factored into project selection and infrastructure design choices, as they will likely have a dramatic influence on transport megaprojects, which typically have business cases built on the supposedly robust foundation of multi-decade demand profile projections. Going forward, however, incremental sensitivity analysis of historical demand profiles will not be sufficient to account for these technology-driven disruptions.

1. Future of mobility

As technology advances, the way people move around urban environments is set to change significantly, making it hard for infrastructure owners to predict the type and magnitude of demand. Numerous fast-moving technological trends are set to influence the future of mobility:¹²

- **Acceleration of connectivity and the Internet of Things.** By 2030, 80 percent (29 percent at present) of vehicles will be equipped with embedded connectivity, with 40 percent of consumers expected to switch car brands for better connectivity and 44 percent expected to allow car to track driving pattern and behaviour, and report to insurance provider, e.g. to personalise insurance policy.
- **Increased vehicle electrification.** From 2014 to 2018 the global electric vehicle (EV) market grew by 60 percent per year, reaching 2.1 million newly registered vehicles in 2018, partly helped by the falling average price of lithium-ion battery packs. EV market share is expected to reach ~30 to 45 percent of vehicles sold in in Europe, US, and Canada by

¹² McKinsey Centre for Future Mobility—studies, analysis and consumer surveys, 2018 and 2019

2030, with 133 million to 190 million EVs expected to be on the roads in China, US, and the European Union by 2030. At the same time, electric buses remain the fastest-growing EV segment (growing at 100 percent CAGR since 2013) and are expected to comprise 75 percent of new bus sales in Europe by 2030—indeed, current-year bus sales in China are over 90 percent electric.

- **Growing demand for shared mobility.** Meanwhile, the shared mobility market size is already large and growing rapidly. Across China, the European Union, and the United States the combined mobility market was over US\$50 billion in 2016, and it has the potential to grow by 15 to 30 percent annually through to 2030.
- **Availability of autonomous vehicles (AVs).** Manufacturers suggest that fully autonomous (Level 4) cars may be available as early as 2020, and over the next decade, the technology is expected to mature enough to enable fully autonomous vehicles. Regardless of the rate of adoption, the system should be robust enough to be able to cover majority of passenger miles. Helped by acceleration in connectivity and IoT plus reduced cost, a pooled self-driving taxi can be up to 60 percent cheaper than traditional ride-hailing services and become competitive with private cars and public transit.

We expect these trends to have several implications for Australia's future infrastructure needs:

- **Increased stress on an already stressed infrastructure.** In an unconstrained adoption scenario, where regulators do little to support or guide these trends through, infrastructure upgrades or policy, mobility trends may result in more cars on roads instead of less and commuter behaviours, in some cases, shifting away from public transport.
 - **More vehicles on the road.** In the short to medium term, private cars (whether human operated or autonomous) are expected to maintain their dominance, particularly in less densely populated Australian cities. Moreover, empty autonomous vehicles and robo-taxis are likely to roam and run errands (rather than remaining parked) and single occupancy vehicles may rise. The combination of these effects could increase congestion in cities by more than 15 percent,¹³ associated with more cars on the street due to transportation of passengers and goods, for example in the AV case with new business models (for example, consignment stock on wheels circling your block), leading to increased demand for road infrastructure.
 - **Impact on public transit.** In the 2020s, the costs of commuting via public transit versus shared, self-driving vehicles may converge. Some travellers could decide to shift—occasionally or structurally—from public transit to shared mobility, as the economics of a door-to-door on-demand offering become more compelling. A simulation model done by McKinsey for the city of Chicago showed adoption of affordable, low-capacity could reduce share of mass public transit by ~50 percent.¹⁴
- **Increased need for vehicle charging infrastructure.** In general, charging facilities and road infrastructure will need to develop to accommodate and stimulate the uptake of electric and autonomous vehicles. The location and type of charging infrastructure required is likely to be different for private EVs versus future shared, self-driving vehicles—for example, the latter would have higher utilisation, favouring fast-charging methods, and could drive autonomously to charging locations in low-cost locations.
- **Staging areas.** AV fleets and shared-ride services will need areas to idle when picking up or discharging passengers; suitable locations might be provided by converting existing parking spots into staging areas accessible to multiple fleet operators.¹⁵
- **Curb modifications.** In most cities, the curb predominantly serves as a space for parking. Going forward, transportation leaders could consider pricing curb space more dynamically, taking demand into account, in order to free up spaces and optimise usage.

¹³ An integrated perspective on the future of mobility, part 3: Setting the direction toward seamless mobility, <https://www.mckinsey.com/~/media/mckinsey/business%20functions/sustainability/our%20insights/the%20road%20to%20seamless%20urban%20mobility/an-integrated-perspective-on-the-future-of-mobility-part-3-vf.ashx>

¹⁴ McKinsey Centre for Future of Mobility

¹⁵ A new look at autonomous-vehicle infrastructure, *McKinsey & Company*, May 2019

This could reduce congestion associated with vehicles circling the block, looking for under-priced street parking—a current problem that will extend into the AV world of the future. At the same time, designating curb space for specific purposes at different times (using signs or beacons that send signals to AVs) could further help reduce congestion. For example, during rush hour, the curb might be a pickup site for AV shuttles that are part of the public transportation system.¹⁶

2. Smart cities—managing demand and improving commuter time and safety

Similarly, increasing adoption of smart-city technology over coming years has the potential to bring multiple benefits to citizens but also have a profound impact on future infrastructure requirements. In this report, we focus on smart city applications within the mobility domain, and define a smart city as a digital overlay on our day-to-day infrastructure—that is the network of sensors that collects data from existing assets; the applications and analytical brainpower that generate insights from this data; and the adoption of technology and changes in behaviour by citizens to utilise their infrastructure in a smarter way.

Globally, numerous cities are investing in this digital overlay and achieving dramatic quality-of-life improvements for inhabitants, although even the “smartest” cities are only realising a fraction of the potential benefits. In a recent McKinsey Global Institute (MGI) report,¹⁷ 50 cities were assessed on their deployment of smart infrastructure in three areas: the strength of the technology base, number and extent of applications, and public usage and satisfaction. This research showed that Australian cities (Sydney and Melbourne) are lagging some leading global cities, largely due to relatively lower adoption of smart-city technologies by residents.

Societal attitudes towards privacy concerns are a potential barrier to the adoption of smart-city technologies. Some cities have started to take account of this issue, one example being Barcelona, which is proactively addressing residents’ privacy, data sovereignty, and data security concerns through a strategic technology plan. This focuses on creating an open-source sensor network that will enable it to retain control of the platform but break down data silos, while also experimenting with applications that invite the public to weigh in on policy-making issues, using technology to increase civic engagement.¹⁸

By 2025, cities that deploy a full range of intelligent mobility applications have the potential to:

- **Cut average commuting times** by 15 to 20 percent, with some workers enjoying even more substantial reductions. For the average commuter, this translates into getting back 15 to 30 minutes every workday—or two to four full days every year.
- **Increase road utilisation** through smarter traffic management and provision of data and analytics for autonomous vehicles, potentially reducing the need for new road projects.
- **Improve commuter safety** through provision of improved traffic information, more sophisticated traffic policing, facilitating autonomous driving, and reducing emergency response times by 20 to 35 percent.
- **Enhance asset life and optimise spend on sustaining capital expenditure (capex)** through predictive maintenance.
- **Reduce greenhouse gas (GHG) emissions by 3%-5%**¹⁷ through a range of Potential mobility-related interventions for smart cities.

We have identified various (non-exhaustive) smart-city interventions relating to transit and mobility with relevance to infrastructure (see sidebar “Potential mobility-related interventions for smart cities”). All of them have an impact on mobility patterns and create modal shifts that need to be considered as part of future transport planning.

¹⁶ A new look at autonomous-vehicle infrastructure, *McKinsey & Company*, May 2019

¹⁷ Smart Cities: Digital Solutions for A More Livable Future, *McKinsey Global Institute*, June 2018.

¹⁸ Barcelona: Smart city revolution in progress, *Financial Times*, October 25, 2017.

Potential mobility-related interventions for smart cities

- **Public transit**—real-time information, interconnected mobility by multi-modal offers (such as apps), scheduling and demand-based micro transit, modern ticketing systems, and digital payment in public transit.
- **Cars and traffic**—predictive maintenance, intelligent traffic signals, congestion pricing, real-time road navigation, dynamic speed limits, dedicated multi-person lanes.
- **Smart parking**—intelligent park guidance system and dynamic tariffs.
- **Other alternative concepts**—sharing (car, bike, scooter), smart parcel.

3. Future of work and automation of the workplace

Automation of the workplace offers the potential to add up to A\$5.8 trillion (US\$4 trillion) to Australia's economy.¹⁹ At the same time, it has far-reaching implications for Australia's infrastructure needs. Crucially, given population and sector dispersal, the level of job displacement will range from a low of 21 percent in inner cities to a high of about 31 percent in some outer suburban and remote areas. While precise travel patterns and changes to business and living locations remain uncertain, one impact is clear: forthcoming major infrastructure planning (transport, energy, utilities) must factor in shifting demographics based on the future of work. The questions to be answered include: Where will work be concentrated and, based on this, where will communities thrive, what impact will this have on work commutes, where will communities dwindle, and what infrastructure should we build to serve them?

These disruptions create new infrastructure investment demand and opportunities for the private sector...

These three macro-trends and the disruptions they bring with them will also create instances of new asset classes. In most cases, these will pertain to smart cities, examples being EV charging infrastructure within cities, improved shared mobility infrastructure, and smart grid investment. For the private sector, this introduces new investment opportunities that may provide attractive economic returns. From a public-sector perspective, these new asset classes may increase the number and diversity of projects competing for funding and selection.

... And affect multibillion-dollar decisions being made today—derisking a priority for government and public authorities

With such volatile macro-trends (future of mobility, smart cities, and future of work), governments and public transport authorities clearly cannot sit and wait for these technology disruptions to play out in real time. Infrastructure decisions need to be made today. And they need to be made in a way that future proofs (as comprehensively as possible) megaprojects against a range of potential outcomes, taking the already changing customer preferences and new technologies into account.

¹⁹ Australia's Automation Opportunity: Reigniting Productivity, *McKinsey.com*, March 2019.

Practically, we suggest five shifts at the city level:

- **An integrated vision for how technology could affect the way that people and freight move around the city.** An integrated view is needed for how these macro trends will impact the movement of people and goods. This will be highly city specific, and depend heavily on the relevant demographics, existing infrastructure, prevalent industrial sectors, and likelihood of adoption by citizens. An integrated view will require cooperation with other infrastructure stakeholders as each new technology will come with costs and benefits to a variety of stakeholders, including infrastructure users, infrastructure operators, regulators, and financing bodies. As such, each of these stakeholders brings different perspectives to how to prepare infrastructure for the future of mobility.
- **Development of scenarios around the impact on transport infrastructure demand generated by radical shifts in technology.** Participants can start by developing a few likely scenarios describing possible future needs. These scenarios should consider upcoming technological developments as well as varying user preferences, and also highlight the expected socioeconomic benefits—outlining an approach to maximise them. For these purposes, sensitivity analyses and statistical techniques (such as Monte Carlo analyses) are insufficient to cater for the multiplicative impact of the three macro trends described above. Instead, governments and infrastructure investors can explicitly model these scenarios and understand the leading indicators for each: for instance, they can perform a geospatial, agent-based simulation to understand how travellers might behave and undertake scenario planning for a city as a whole.
- **Translation of scenarios into future-proofed strategic prioritisation of capital and resources at a portfolio and project level.** These scenarios can then be translated into a clear infrastructure development plan that brings a level of specificity to which projects should be constructed. Project- and portfolio-level decisions will also need to account for the benefit of flexibility: for example, by valuing the “real options” created through a stepped approach to development with the explicit intention to either discontinue or pivot as circumstances change. It is critical to understand what decisions have to be made today, and what decisions can be postponed until further data are available.
- **Embedding new competencies and processes.**²⁰ This includes building capabilities around active mobility planning—enabling multi-modal journeys that are seamless and applying the right pricing logic (e.g. to avoid congestion), as well as finding ways the new technology can be synergistic with the invested assets and not undermine their value. Incorporating forward-looking components such as embedded sensors into new, rebuilt, and, existing infrastructure, building electric infrastructure to support charging network, standard technical specifications that enable data sharing and best-in-class data privacy standards will pave the way for AVs and other future technologies down the line. However, most operators don't reflect these features in current planning and investment cycles—they tend to plan on a project-by-project basis, backed by a relatively static regulatory framework of technologies that are already approved, widely available, and easily deployed. Preparing for forthcoming faster development cycles and the rollout of various integrated platforms will instead require operators to acquire new competencies in planning, maintenance, and operations (often through partnerships with non-traditional technology suppliers), potentially by building a separate business unit to bypass standard company processes. As an example, Norway has established a separate road agency for infrastructure innovation, to speed up cost-efficient development and construction of selected highways.

²⁰ Building the infrastructure for the future of mobility, McKinsey Voices of Infrastructure, July 2019.

- **Creating a roadmap of initiatives and enabling actions (for example, application of effective regulation and incentives, changes to planning, creation of a “Future Mobility Hub”, and setting clear technology standards and safety requirements) to deliver the vision.** In the context of the above, governments and public-sector agencies need to be able to understand the regulatory and governance ecosystem that will best enable the vision to be delivered. As technology pushes mobility forward, it will be crucial to ensure regulations are in place and rapidly updated. In addition to essential safety tests and approvals, regulations can take many years to design and implement, while innovation cycles can upend industries in under a year. Unaddressed, we expect regulation modifications to lag five to seven years behind the readiness of technologies such as autonomous driving—delaying the full integration of new technologies into the transport system. To expedite and facilitate development of appropriate regulations, manufacturers and operators will need to collaborate with regulators to adapt approval processes and help keep pace with accelerated technology development. Regulators, manufacturers, and operators need to work together on putting in place the right regulations and incentives as well as the enabling initiatives required to knit together forecasting, decision making, and execution of future infrastructure needs to effectively improve performance on the five indicators²¹ that characterise a transit system (availability, affordability, efficiency, convenience, and sustainability).²²
 - **Availability**—Enable infrastructure to accommodate more passenger-kilometres through increased access to seamless mobility that is inclusive of all residents by expanding accessibility and affordability of shared mobility in underserved areas such as lower income communities.
 - **Affordability**—Reduce cost per trip by providing mobility choices that are equitable and affordable for all. For example, In June 2019, the Washington D.C. transit agency announced that ride-hailing heavyweight Lyft will soon begin providing shared rides for late-night workers in the D.C. area under a one-year pilot program Metro is launching to help make up for the lack of early-morning service on its rail system. The transit agency announced in a release Monday that people can apply for the program, which involves an up to \$3 subsidy per ride for as many as 40 rides per month, for service starting July 1 2019.²³
 - **Efficiency**—Reduce congestion and average time travelled per trip through zoning, streamlined traffic-related fees and taxes into an integrated congestion price structure, V2I technology for curbside congestion and parking management, zombie taxes for robo-taxis and improved efficiency of public transit systems.
 - **Convenience**—Increase the number of point-to-point trips through a seamless mobility experience guided by data transparency and privacy through implementation of a smart ticketing system, electronic services, integrated data infrastructure to support multimodal platform and traffic management applications etc.
 - **Sustainability**—Reduce greenhouse gas emissions and enable a system that contributes to more sustainable, healthy and liveable communities by promoting and enabling and incentivising the adoption of personal and shared EVs, and fully electrifying public transit and sub-contracted public transit systems.

²¹ An integrated perspective on the future of mobility, part 3: Setting the direction toward seamless mobility, <https://www.mckinsey.com/~/media/mckinsey/business%20functions/sustainability/our%20insights/the%20road%20to%20seamless%20urban%20mobility/an-integrated-perspective-on-the-future-of-mobility-part-3-vf.ashx>

²² McKinsey Center for Mobility City Pilot – Future Urban Mobility, April 2019

²³ Curbed Washington DC <https://dc.curbed.com/2019/6/25/18758594/metro-wmata-late-night-service-lyft-rides>

Chapter 2: Rethinking project selection and prioritisation

In an environment where potential infrastructure projects far exceed the finite capital budget available to build them, the first critical lever to consider is optimising project selection.

While infrastructure investment decisions inevitably involve political considerations, it is critical to ensure these decisions are founded on a robust and consistent fact base. A core element of infrastructure decision making is the business case; this analyses the costs and benefits of a project and sets out the arguments for proceeding or rejecting it (see sidebar “Australia’s current approach to business case evaluation”). Australia’s approach to business-case development is relatively mature, being sophisticated and methodical—for example, every Commonwealth infrastructure proposal over \$100 million is reviewed by Infrastructure Australia. However, we note that a number of challenges are beginning to emerge.

Australia’s current approach to business case evaluation

Two metrics underpin the core of most business-case evaluations: the benefit-cost ratio (BCR) and net present value (NPV). BCR is the most commonly referred to metric when comparing projects. Wider economic, social, and environmental benefits are considered in a qualitative manner.

Five challenges to the traditional business case-led approach to project selection and prioritisation:

1. **Limitations of the benefit-cost ratio.** BCR remains a useful metric to understand and compare a project’s value. However, we also see fundamental flaws in this method: it can create *false precision* by reducing projects to summary statistics and can be susceptible to bias. BCR and net present value (NPV) simplify what are often complex, multifaceted project considerations into single numbers. The upside is that this makes it easy to communicate and explain a project’s value to stakeholders; the downside is that it creates a false sense of precision. Not only is it nearly impossible to accurately predict future costs and benefits of a project, as the drivers of these are complex and difficult to model, but BCR and NPV are both highly sensitive to changes in core assumptions—for example, discount rate. Moreover, these metrics cannot and do not cover every relevant consideration when it comes to project selection. Some factors, such as community support, are difficult to quantify and assess, yet play an important role in a project’s success. For example, the Sydney Harbour Bridge, now a national icon, probably wouldn’t have been built if the original decision had been based solely on the business case. It didn’t generate a positive cash flow for 20 years, but today carries over 160,000 vehicles a day and generates significant cultural and tourism benefits for the city. Equally estimates tend not to take account of factors such as flexibility or the potential impact of disruptive mobility trends.

2. **The business case process can suffer from inherent bias.** This can inflate project benefits, and also appear to favour public opinion or decisions already taken. More helpful would be a focus on potential scope and delivery options—with differential customer and community outcomes—for government consideration. Kahneman and Tversky (and subsequent behavioural economists) found that optimism bias applies to both estimates of costs and benefits. Thus, errors of estimation do not cancel each other out, as Hirschman would have it—the exact opposite happens, errors generally reinforce each other. Indeed, as of 2006, the United Kingdom, Denmark, and Switzerland will not fund projects that do not address the potential for optimism bias in their business cases.²⁴
3. **Project selection will always be political to some extent.** A common refrain within the infrastructure sector is that infrastructure decisions can be influenced by the political cycle. Over the ten years 2006–16, swing states received 46 percent more federal funding per capita for transport infrastructure than other states.²⁵ Marginal seats received almost 3.5 times more infrastructure funding than safer seats.²⁶ Decision makers need to make trade-offs in view of political considerations; however, there is an opportunity to help make these decisions better informed. In many cases, it appears megaprojects are announced by governments well before a business case and options analyses have been completed, leading to analysis sometimes being undertaken to justify projects that will go ahead regardless of the outputs.
4. **The process is time-consuming.** The extensive business case work that is usually carried out for a major project can take over 12 months to prepare, yet these timelines, as discussed above, are often incompatible with decision timeframes—election cycles and funding availability often mean that project decisions are made and announced before the business case can be completed. At the same time, the process is also resource-intensive.
5. **Selection and prioritisation of spend are not always carried out on comparable projects.** Projects with different objectives and diverse expressions of costs and benefits need to be evaluated differently. Yet, metrics such as BCR and NPV encourage comparison and relative “ranking” of projects with vastly different objectives and contexts. In many cases, such comparisons are not meaningful in practice, as the projects are too different and should be assessed against criteria more specific to each one (Exhibit 6)—hence this approach can unfairly deprioritise projects. For example, some rural projects are unlikely to have a favourable business case vis-à-vis urban projects if these types of project are directly compared one with another, despite the underlying drivers for the two types of project being vastly different. A further issue with business case evaluations is that the methods of calculating BCR and NPV can vary, with different assumptions and inclusions used depending on the project and the proponent. Existing guidelines on business case preparation are applied inconsistently,²⁷ making it difficult to compare different projects using these numbers.

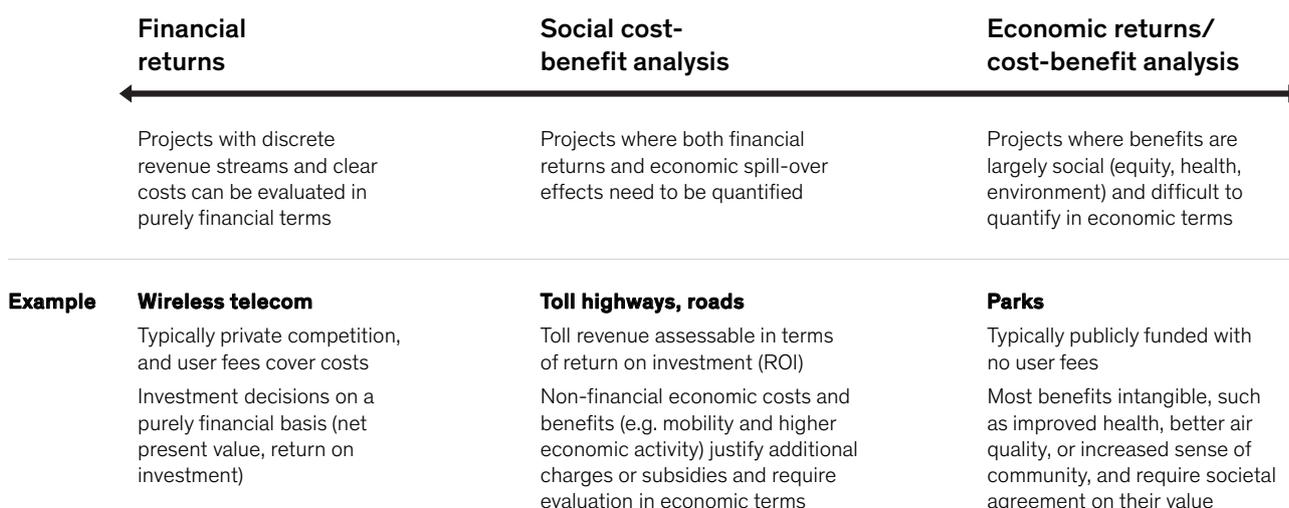
²⁴ Bent Flyvbjerg, What You Should Know About Megaprojects, and Why: An Overview, Draft 9.2, 2014

²⁵ <https://grattan.edu.au/report/roads-to-riches/>

²⁶ <https://www.smh.com.au/politics/federal/the-1-billion-cost-of-pork-barrelling-revealed-20180117-h0judh.html>

²⁷ <https://www.asbec.asn.au/wordpress/wp-content/uploads/2017/10/171018-ASBEC-Bang-for-Buck.pdf>

Infrastructure projects can vary widely in terms of how their costs and benefits are expressed—and need to be evaluated differently.



SOURCE: McKinsey Global Institute analysis

Four ways to improve our approach to project selection

- **Focus business-case analysis on “what really matters”.** We can improve analytical rigour during business-case evaluation by ensuring metrics are tightly linked to strategic objectives and account for different future scenarios, so the metrics will more accurately reflect reality. Equally, if state governments and project proponents nationwide can use consistent methodologies when evaluating business cases, this will make it easier to compare projects accurately.
- **Apply debiasing techniques to improve decision making.** Cognitive bias can skew decision making and outcomes via the judgments that people make. Although it is impossible to fully decouple cognitive bias from infrastructure investment decisions, one way to keep this in check is through conscious inclusion of debiasing techniques and broader awareness of behavioural economics.

Although individuals will always struggle to overcome biases on their own, organisations can succeed with the support of systems.²⁸ Best-practice organisations have explicit discussions around uncertainty, fully transparent criteria for approval, and create an atmosphere where debate is directed by skills and experience (not hierarchy). Such organisations actively search for information to contradict the investment hypothesis. For example, in the private equity (PE) sector, investment decisions are debiased through a number of systematic countermeasures. These range from the deeply analytical (such as real-options valuation and reference-class forecasting), through to practical social dynamics (such as “pre-mortems” and “devil’s advocate”). Some investment companies also run an “anti-portfolio” to track their decision making retrospectively. This allows them to identify investments they missed out on, reflect on what decisions they should have made, and incorporate past learnings into future decision making.

²⁸ Daniel Kahneman, Nobel Prize Winner in Economics and McKinsey work on Behavioral Economics and Debiasing Investment Decisions March 2018.

Infrastructure decision-making organisations can consider formally embedding such roles and structures to minimise bias. These structures should drive analysis and encourage the use of organisational, analytical, and debate countermeasures. Incorporating these techniques will help to ensure infrastructure project selection is linked back to the objective function (ensuring an outcome that optimises benefits and cost issues based on the specific underlying constraints and decision factors).

- **Develop the capability to perform rapid options analysis.** The extended timeframes associated with business-case development conflict with shorter decision-making timeframes, limiting their usefulness. Instead of relying on long, detailed business cases, governments and other infrastructure investors can undertake rapid strategic options analysis during the very early stages of an infrastructure proposal with key high-level decision makers (for example, at secretary and minister level). Such analysis would be timely enough to inform decisions before they are announced, as opposed to being used to justify decisions retrospectively.

Infrastructure professionals should consider opportunities to provide robust yet timely analysis for government decision makers. Government departments could build capabilities to be able to rapidly develop, quantify, and assess the customer and community benefits of alternative modal (for instance, autonomous busway versus heavy rail versus light rail versus motorway) and scope options for a new transport corridor, within a four-week period. Premiers and senior ministers could be made aware of this capability, such that rapid options assessment would then be very likely used by the government prior to announcing a specific mega-project. Government may still choose to pursue their preferred project, but it would be an informed choice based on clear trade-offs presented.

- **Prioritise infrastructure projects within specific investment categories.** To make comparable investment decisions, project sponsors can allocate potential projects into investment categories. Categorising projects will allow sponsors to: 1) allocate capital across categories, 2) compare and prioritise spend within each category, and 3) ring-fence investment decisions from political influences to the extent it is appropriate to do so. We believe Australian decision-making authorities are generally very good at categorising decisions on the basis of what is mandatory and what is discretionary. However, discretionary infrastructure can then be broken down into a further three categories to improve decision making, using needs-based assessment: additional capacity, extending coverage, and strategic importance (Exhibit 7). Rather than comparing all discretionary spend projects one to another based on their BCR alone, projects can be grouped into the relevant decision package, top-down capex envelope set by decision package, bottom-up budgeting done by package, and prioritised within these packages (based on need), enabling more effective project selection (Exhibit 8). Projects can then be prioritised within investment categories, across states and across different project types. In Australia, this would need government to consider infrastructure more holistically (rather than on an individual project basis).

Exhibit 7

Potential infrastructure projects can be grouped into four investment categories.

		Investment driver	Examples		
Discretionary	Mandatory	Projects that need to be completed to fulfil legal, safety or regulatory requirements	Improving safety of electricity infrastructure following Black Saturday		
		Capacity	Projects required to provide additional capacity to meet increasing demand	High capacity metro trains	
		Coverage	Projects required to extend infrastructure coverage to a new area or population	Perth Metronet	
	Strategic	Projects of national significance or future strategic importance intended to unlock broader economic or social value	Public parks, sporting stadiums		

Exhibit 8

Prioritising projects based on investment categories enables more effective project selection.



Chapter 3: Driving value through innovative approaches to project design

Introducing innovative approaches to design can improve project outcomes.

Infrastructure design, of course, has numerous influences on project value across multiple dimensions in terms of costs (both capex and opex), disruption during construction, and project outcomes (including adaptability for future needs). Indeed, after project selection, the single biggest lever to improve outcomes and enhance project value is to introduce innovative approaches to design and engineering (Exhibit 9), and design-to-value frameworks that focus on delivering defined benefits and functions at lowest cost.

However, this opportunity is often missed for five reasons.

1. **A capital works frame, rather than a whole-of-life optimisation frame.** Often, capital budgetary constraints and lack of cross-functional stakeholder involvement in investment decisions means decision makers can take the “capex view”, versus whole-life cost. On occasion, this can lead towards a design with lower capex but higher opex, in contrast to a design with higher capex and a lower total cost of ownership.

Exhibit 9

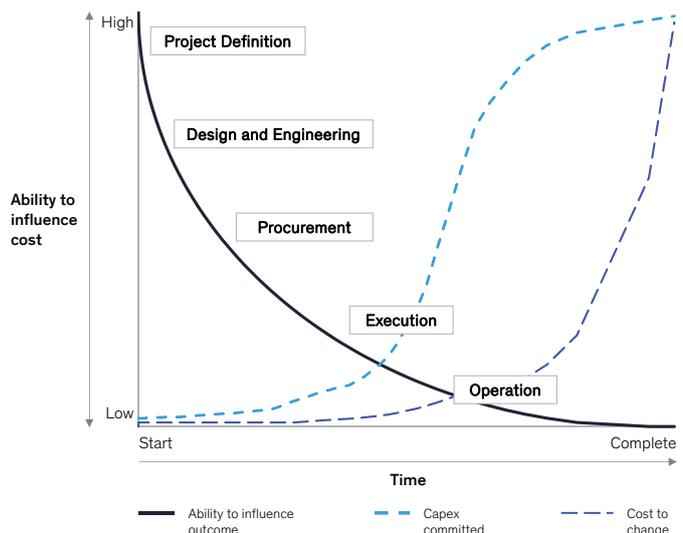
The biggest opportunity to influence the cost and outcome of the project is during the design phase.

How does design influence project outcome?

 Overregulation, unnecessary constraints Wrong project, fettered delivery	 Constructability More difficult or time consuming to execute
 Complexity Unnecessary complexity	 Overdesign Direct cost of materials
 Ambiguity Increased # of RFIs	 Non-coordinate Site instructions, claims
 Errors Redesign, delays execution	 Opex Increases operational cost

Design directly influences construction productivity and project success by influencing time required to complete an activity, including rework

Ability to influence final cost over project life



SOURCE: Construction Industry Institute and McKinsey analysis

2. **Lack of integrated perspective and ownership.** In most cases, project-value analyses are performed at the concept or feasibility phase to clear an investment-decision gate. Frequently, design optimisation is left to engineering teams for consideration, and they may not understand the trade-offs or be well positioned to take trade-off decisions. Decisions that are not well thought through—for example on employer’s requirements, basis of design and/or specifications—can destroy project value or, worse, may fail to meet project objectives. Design optimisation requires a top-down approach based on defined functions to deliver defined benefits, and often requires strong decision makers with good judgement around trade-offs between engineering, construction, cost, benefits, and future operations—this is not possible unless there is review by a cross-functional team.
3. **Lack of design-to-value framework and capabilities.** Unlike, for example, quality assurance or even risk management, most project planning, development and delivery does not incorporate a rigorous framework for progressive, continuous, and stage-gated design to value or design to cost.
4. **Misaligned incentives.** Where different teams are focused on achieving KPIs under individual contracts, the engineering consultant may be focused on delivering the design drawings within a short time span, vendors may seek to reduce cost by adopting off-the-shelf solutions, while contractors may be focused on executing/building high earned-value tasks to manage their cashflow. The consequent conflicts of interest can result in the various parties not considering or, worse, being unaware of the implications of their design choices. Moreover, both confirmation bias and anchoring²⁹ can complicate capital allocation, which involves making choices in the context of significant uncertainty.
5. **Regulation preventing design innovation.** Where designs are overly constrained either by highly onerous requirements by regulators or overly restrictive approval conditions, value can be—and often is—destroyed. Internal stakeholders also impose unnecessary regulation in many ways. For example, standards groups within agencies can stipulate overly restrictive, capital-intensive, and often obsolete standards and specifications; and review processes, such as design or construction certification processes can unintentionally prevent innovation because the risks to project participants (including delay risk) make changes not worth pursuing, particularly during delivery—this includes, for example, independent verifiers processes.

Four ways to transform infrastructure design

The sheer scale and complexity of the infrastructure program implies a volume of concept and detailed design work that is very challenging to control if it is to remain consistent with defined project benefits and functional requirements. Accordingly, stakeholders globally are looking for ways to move beyond traditional “value engineering” as they seek to capture the cost and schedule reductions required to deal with the scale and complexity of today’s infrastructure megaprojects. They can look to innovation across four design dimensions.

- **Apply agile methodologies to the design process.** Agile in its simplest form adopts a new way of working to break down silos and increase organisations’ metabolic rate. It brings dedicated contributors from different disciplines into the same room to work “shoulder to shoulder”. Requirements are gathered through discussions and visual design, while the business and customers see the output on a weekly basis and “course correct” as necessary. The agile methodology requires longer explanation, but in essence its key features when applied to infrastructure design and development include:
 - *Co-located cross-functional teams (“squads”).* A team comprises fully dedicated design, procurement, finance, construction, and operations professionals, resulting in faster and better value engineering trade-offs.

²⁹ Confirmation bias refers to the interpretation evidence to affirm existing theories; anchoring refers to a situation where an individual relies disproportionately on an initial piece of information.

- *Sprints*. A key element of the agile approach is for everyone to work in a time-boxed manner, with regular check-ins (“stand ups”) and report-outs (“showcases”), to produce outputs such as design options. This provides the opportunity to improve output after stage-gate reviews and feedback (for example, through “retrospectives”).
- *Customer focused*. End-user needs are constantly discussed and used to optimise for time and cost during construction and operation.
- *Information transparency*. This minimises any information asymmetry between owner, operator, contractor, and vendors—better information improves predictability of performance.

- **Adopt and institutionalise a zero-based approach to design—“design to value” (DTV)**. In contrast to traditional approaches, DTV optimises the design of a selected project through top-down review based on the business case, including benefits sought (economic, social, environmental), the context and constraints, and functional requirements, with the intention of identifying the “minimum technical solution” (MTS) that delivers the requirements—ideally with material capital and whole-of-life cost savings while maintaining or improving safety, quality, and constructability baselines in the early stages of design.

DTV adopts a cross-functional, cross-organisational approach, working in an integrated design team, and potentially includes external stakeholders. The team operates within an agile-inspired framework to rapidly identify and iterate key decision drivers and identify viable alternatives, with frequent touchpoints with senior decision makers. DTV seeks to ensure that project objectives are met, but also that longstanding assumptions or practices are challenged and discussed at senior levels, if they are identified as being bottlenecks to creating significant value. It is important to note that this approach is not a onetime activity; it should be undertaken at various stages of the project and also inform the procurement process. Where we have seen owners and contractors applying this approach to infrastructure projects, the impact is substantial and well above traditional value engineering exercises—benefits captured are often in the range of 15 to 30 percent cost savings.

- **Industrialise design across a portfolio where appropriate—a manufacturing approach to common design and construction (D&C) elements**. Currently, multiple factors discussed above combine to prevent a more industrial or production-oriented approach to appropriate project components. Although individual infrastructure projects are generally highly dependent both on their context on the ground (in the natural and built environment) and in the community, there is potential for significant savings on design and delivery costs and time on projects. This can drive sustainable medium- to long-term supply-chain performance by unbundling and managing common elements at a portfolio level through a manufacturing or production-based approach.

This needs a broader portfolio concept, not just at institutional level but also across institutions and a reframed approach to project engineering. At portfolio level, we believe that there is opportunity to “productionise” more of the design of the many, somewhat similar projects. This can reduce cost, provide greater supply chain certainty, and improve productivity—so increasing government’s ability to deliver its ambitious programs. Examples include standardisation of designs and specifications and modularisation of segments, which will not only have an impact on upfront costs (capex) but also on ongoing operations and maintenance costs (opex).

Generally, however, recognising the unique environment of each project—and, within that context, the dependency of both solutions and services on the specific construction methods adopted—it is unlikely to be efficient to fully adopt a manufacturing approach. Nevertheless, there are numerous common elements across portfolios that could be more efficiently delivered by separate procurement at a portfolio level: for example, precast and modular components or the supply of ubiquitous materials.

- **Apply framework and capabilities.** Incorporate a rigorous framework for progressive, continuous, and stage-gated design to value or design to cost. We suggest that such a process should be incorporated into all planning and delivery. It should continue after procurement and should not be restricted based on contract risk allocation, to ensure that value is not lost for project participants after risk is allocated, depending on the circumstances that arise. The process should be based on clear definition of functional requirements and benefits sought with a continuing focus on delivering the defined functions and benefits at the lowest cost. Indeed, any change to the benefits being delivered should require a resubmitted business case to the project investment decision makers (often cabinet or its committees).

Chapter 4: Innovating the commercial framework

Improving contractual structures and aligning incentives between project owners and the supply chain in Australia can help improve project outcomes and increase market appetite and competition.

Today, major public infrastructure projects in Australia tend to be delivered through large outsourced contracts. This involves single-point private sector accountability for delivery of the defined project, and little ability to adjust delivery post-award either to add value or to prevent value destruction. This approach has served Australia reasonably well over an extended period; aspects of current practice (developed in the 1990s) have effectively solved many of the problems prevalent in the late 20th century, such as a lack of clarity around risk allocation. Nevertheless, in the context of high risk and low or negative profit margins achieved by contractors, contractual frameworks and the process of procuring private-sector counterparties may now benefit from reform, both from a government and a private-sector perspective.

A 2017 study³⁰ of performance outcomes for Tier 1 contractors involved in major PPP and D&C projects completed in Australia since 2000 found that, despite relatively routine initial tender margins of 6 to 12 percent, actual margins were typically much lower and turned negative in more than 40 percent of cases—sometimes significantly. Outcomes like this are not sustainable. Indeed, there is current evidence of declining interest in major projects at a time when industry participation needs to increase to deliver the anticipated infrastructure pipeline. Tender process and contractual barriers that hamper government and industry's ability to adapt and innovate during execution need to be addressed. This is particularly important to mitigate negative delivery-phase impacts on the community and wider stakeholders. Encouragingly, government and industry are in the process of pursuing initiatives to address some of these identified issues. For example, the 2018 NSW Government Action Plan³¹ aims to improve partnership with the private sector through better procurement and contracting measures.

We have highlighted five areas in which contracts and procurement practices may be inhibiting optimal outcomes.

1. **Contractors and suppliers consider contractual structures and incentives to be among the principal hurdles to achieving better project outcomes.** A global MGI survey among project owners, contractors, and suppliers, which asked respondents to rank the top ten root causes for achieving suboptimal project outcomes, showed that contractors and suppliers placed contractual structures at the top of the list (Exhibit 10). In the context of constrained supply, this perception among private sector participants could reduce competition and increase cost in the future.

³⁰ Peter Ryan and Colin F. Duffield, *Contractor Performance on Mega Projects—Avoiding the Pitfalls*, *University of Melbourne Paper*.

³¹ NSW Government Action Plan: A ten point commitment to the construction sector, *NSW Government*, June 2018, <http://www.infrastructure.nsw.gov.au/media/1649/10-point-commitment-to-the-construction-industry-final-002.pdf>.

Contractual structures cited by contractors and suppliers as the top root cause hindering project performance.

Root cause	Rankings (1 highest, 10 lowest)			
	Overall	Contractor	Owner	Supplier
Design processes and investment are inadequate	1	2	2	4
Contractual structures and incentives are misaligned	2	1	5	1
Insufficiently skilled labour at the frontline and supervisory levels	3	4	3	5
Increasing project and site complexities	4	3	4	3
Poor project-management and execution basics	5	6	1	6
Bespoke or suboptimal owner requirements	6	5	6	10
Industry underinvests in digitisation, innovation, and capital	7	7	7	2
Extensive regulation and cyclical nature of public investment	8	8	8	7
Industry is highly fragmented horizontally and vertically	9	9	9	9
Informality and potential for corruption distort the market	10	10	10	8

Note: Number of respondents = 210
SOURCE: MGI Construction Productivity Insights Survey

2. **Rigid risk allocation contracts often deter collaboration to find better solutions and improve mutual outcomes.** Typical risk allocation contracts are designed to protect against project downside—mainly for the owner—and not for post-award cooperation to enable project value improvement. The contract structure and rigid probity environment make win-win cooperation post-tender submission very difficult and even risky to the contractor because of time, cost, and liability penalties. Rigid risk allocation can result in contractor executives focusing valuable time and resources on financial management, rather than productivity enhancement. Meanwhile, the owner can also face disincentives to engage in such cooperation due to probity concerns and the perceived risk of taking accountability away from the contractor.

Allocation of all design and construction risk to contractors—with balance-sheet-threatening liability limits—does not prevent some risks from manifesting, particularly those that are not fully in the control of the party responsible for that risk. In urban infrastructure projects, for instance, there are many substantial external risks associated with the community context, the physical environment, and interfaces. When a project goes wrong or performs poorly, the owner is always impacted negatively regardless of the contract terms—and measures within contracts such as allocation of financial consequences often do not adequately prevent or offset the pain.

In these circumstances, it is often in all parties' interests to seek different outcomes by working together: for example, by adjusting the staging of completion and opening, despite the contractual implications.

3. **Transaction complexity and regulatory burden reduces market interest and can add unnecessary cost and delays.** Australia is continuing to increase its focus on simplifying tender processes, submission requirements, and the regulatory environment for construction by reducing engineering requirements, streamlining permitting and approvals processes, reducing the number of procedures, and increasing the quality of rule-making. Nonetheless, the cost of tendering and associated regulatory burden remains high—including, for example, over 100 planning approval conditions that are often allocated to contractors, including many outside their control. To offset the high cost burden of bidding for major projects, government tender costs are sometimes paid in part by government to unsuccessful tenderers; ultimately, of course, this additional cost remains a burden on the overall cost of the asset and the portfolio. Overall, the regulatory and contractual burden can add to construction cost and delivery duration and, can also act as a significant barrier to design and construction innovation during delivery. Meanwhile, tender process durations of up to two years (from calls for expressions of interest to contract execution) also act as a barrier to interest from international companies.
4. **Low contractor confidence in longer-term order book prevents productivity-enhancing investment.** Almost every project is separately tendered, even in the context of the major project portfolio, both within and across agencies and states. The resulting uncertainty reduces the incentive for contractors to invest for the longer term—in staffing, technology adoption, and equipment—with an inevitable lost opportunity for productivity improvement. A balance is required between ensuring appropriate competition and creating certainty. Where governments have tendered programs of work (rather than individual projects), such as the level-crossing removal program alliances in Victoria, these have often delivered fast, affordable project and program outcomes.

In recent years, government has been publishing project pipelines, as a way to offer clarity and increase transparency, but these pipelines become less clear as we look forward, beyond the four-year budget forward estimates. Government is often reluctant to publish plans for longer-term projects prior to firm political commitment, and therefore forward projections can show activity levels reducing when often government is planning to sustain or increase them. To address this issue, it is possible for suitably qualified medium- to long-term information to be provided to industry without the community or industry perceiving such projections as binding commitments. Greater longer-term transparency and certainty can boost supply chain confidence and commitment, and encourage investment. The resulting increased level of preparation and investment can help improve the quality of bids and construction productivity over the longer term.

5. **Construction-phase impacts on communities and stakeholders are increasingly important in the context of major urban capital works.** With major waves of simultaneous construction across cities, the impact of multiple construction projects can be a significant issue for communities and wider stakeholders. Delivery-phase impacts and methods of mitigation are fundamental to project success, yet current risk-allocation arrangements tend to focus on construction as a solution (what is delivered) rather than a service (how it is delivered). Both are important. Many recent projects have been or still are being materially prolonged relative to the tender schedule by unexpected difficulties with utilities, access, and the legitimate needs of affected communities—this can add cost and cause extended, sometimes increased, disruption. This challenge is likely to be exacerbated in the near future as Sydney and Melbourne undertake major road and rail tunnel projects in their central business districts and surrounding inner suburbs, alongside major airport works.

Mitigating the issues to deliver additional value

In response to the various issues described we have identified a number of ways to reform the system to deliver increased value for stakeholders.

- **Streamline the regulatory burden.** Engagement between project owners and external stakeholders—particularly planning authorities, environmental agencies, utility companies, and federal bodies—should be enhanced to reduce unnecessary regulation. For example, reducing rail possession and other hours-of-work restrictions may both improve performance and improve outcomes for affected communities who may prefer higher impact over a shorter period. These issues are particularly important given the aggregated impact of sustained infrastructure development on communities during delivery—construction is a service not just a solution.

Similarly, removing all unnecessary technical specificity to boost innovation, reduce cost, and increase flexibility and resilience during delivery can add value. If government continues to prefer single-point D&C accountability, industry can be encouraged to innovate during tender and be allowed to continue to innovate during delivery within the agreed project requirements.

Equally, when opportunities arise to increase value or mitigate value destruction during delivery, such opportunities should be enabled by the regulatory environment. For example, time-consuming change processes often mean that value-creating changes to designs, construction methods, or other initiatives are simply not offered by contractors.

- **Increase collaboration in contracting.** It is now common practice on large projects for authorities to engage with potential contractors throughout the tender process. However, a more effective and innovative contest of ideas could be facilitated through greater collaboration prior to contract award. While probity processes to “level the playing field” will remain important, tenderers can be encouraged to capitalise on their capabilities to challenge the tender requirements in order to create value without the risk of being non-compliant. In order to increase collaboration post award, contracts could be adjusted to include suitable proactive responses before or alongside delay or cost claim mechanisms. For example, contracts could mandate that the parties identify and seek to cooperate without prejudice to risk allocations in response to material delays, disruptions, and value-creating opportunities.

Full risk-sharing through alliances is the most comprehensive form of collaboration through the life of a project, whereby design, construction, and owners’ risks are shared by the parties rather than allocated. In recent years, alliancing appears to have been used only in very limited circumstances—in some 3–5 percent of cases during 2017–18, albeit accounting for 10–15 percent of total value across all contracts.³² Properly managed, the efficiencies engendered through aligned incentives and the removal of contractual processes and barriers to cooperation can improve productivity and project outcomes for all parties, particularly in complex, urban operational, community and environmental settings.

In addition to the “hard” aspects of contractual incentives and risk allocation, less adversarial contracting could be an important catalyst for transformation of the culture of the infrastructure industry towards greater cooperation among public and private sector participants.

³² Australian Infrastructure Metric reports, Infrastructure Partnerships Australia, 2017 and 2018.

- **Optimise performance management arrangements and introduce framework agreements for infrastructure design and construction.** Using a cross-government performance management scheme (with contractors and designers evaluated according to their performance) can foster trust, while also building high performance and the right behaviours for sustainable project outcomes and constructor business performance. As confidence rises in the use of such a scheme, there are likely to be significant benefits to industry (removing fragmentation, building pipelines, improving talent retention, improving profitability) and for government in terms of improving delivery performance and outcomes.

Framework agreements can also drive improved performance and outcomes, and they could be used more frequently: the designers and contractors that perform could be rewarded with additional projects over the longer term. Continuous process improvement could be built into framework arrangements with independent governance and quantitative assessment, while open-book pricing could be a necessary component of longer-term framework agreements.

- **Encourage competition by reforming the tender process and evaluation.** When competition is based purely on the price of an individual project, there is high risk that all parties focus on low bid cost rather than innovation to optimise cost of the asset through life or end-customer benefits. Moreover, there is often low correlation between low bid cost and cost at completion. Tender evaluation processes and criteria can be carefully designed and implemented to get the best from the market, not just the cheapest. Some potential shifts for discussion are offered in Exhibit 11.

Exhibit 11

Potential ways of improving tender submission requirements and evaluation processes.

Ideas for improving tender submissions	Ideas for improving tender evaluation
<ul style="list-style-type: none"> — Remove the requirement for any documentation that is unnecessary for comparative evaluation. — In allocating potential liabilities, consider excluding low likelihood but high financial consequence liabilities, especially those outside the contractor's control. — Minimise design requirements to those required to identify value offered and enable pricing. Allow and encourage innovation and resilience through the delivery phase by providing design flexibility wherever practicable. 	<ul style="list-style-type: none"> — Include government performance management evaluation from previous projects. — Directly link the evaluation process to specific success criteria for the project. — Make the evaluation criteria more transparent so bidders can confidently understand what the client values and offer (only) this. This is particularly important where criteria (including weightings) are in tension most specifically between capex, whole-of-life (WOL) cost, and non-cost outcomes (time, community, jobs, environmental impact). — Risk-adjust prices and measure against the offered value and potential changes during delivery, accepting that there will be contingent events where risk allocation cannot be efficiently codified in advance and need flexible, collaborative responses when they occur. — Consider reverse auction techniques such as selecting the second-lowest (risk- and value-adjusted) tender to encourage industry to prepare high-value and low-price tenders but not to take reckless positions through the tender box price.

- **Portfolio management.** Within portfolios and potentially within individual megaprojects, optimising package size, trade mix, and timing can improve access to market capacity and foster effective, sustainable competition. Outcomes can be improved by thorough supply-chain management across the whole engineering and construction market (including between infrastructure sectors—transport, utilities—and between the states) as well as by fine-tuning timing so that industry can organise to compete effectively. A national infrastructure body such as Infrastructure Australia could develop a system to monitor portfolio-level activity at a more granular level and provide detailed information to the states and delivery agencies to inform decision makers of capacity constraints and to optimise timing. For example, there are likely to be times over the coming years when engineering design demand peaks will benefit from timing shifts between projects of several months to enable sufficient capacity. There have also been circumstances in previous infrastructure booms when there has been spare capacity in “Tier 2” construction companies while major companies have been at or beyond capacity; unbundling projects in such circumstances may unlock additional market capacity and improve project outcomes.

Chapter 5: Enhancing industry capability and capacity

Innovative ways to address skills shortages and poor construction productivity can drive a step change in industry performance.

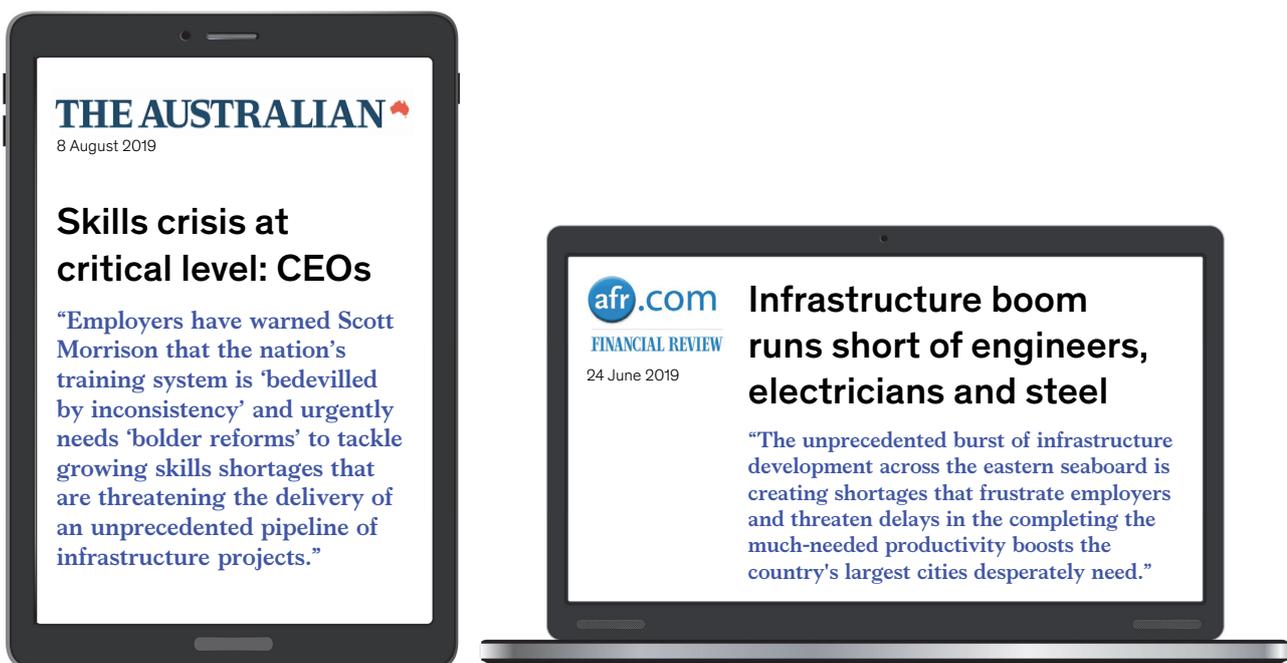
Given the unprecedented scale, intensity, and complexity of Australia’s infrastructure investment over the next five years, there will be immense pressure on public-sector authorities across the nation as well as other actors in the sector mandated to deliver their respective programs of work. A major factor in this will be the availability of suitably qualified talent. In this context, the skills-shortage issue has been well publicised (Exhibit 12).

We analysed three possible forecast scenarios for construction employment demand based on the projected infrastructure spend:

- **Worst-case scenario**—construction productivity (measured as total workers employed per Australian dollar spent) remains at 2018 levels.
- **Conservative scenario**—construction productivity levels return to the average productivity level from 2013–18.
- **Productivity improvements scenario**—construction productivity increases by 10 percent in five years from 2018 levels.

Exhibit 12

Skill shortages have been well documented.



SOURCE: The Australian Financial Review, The Australian

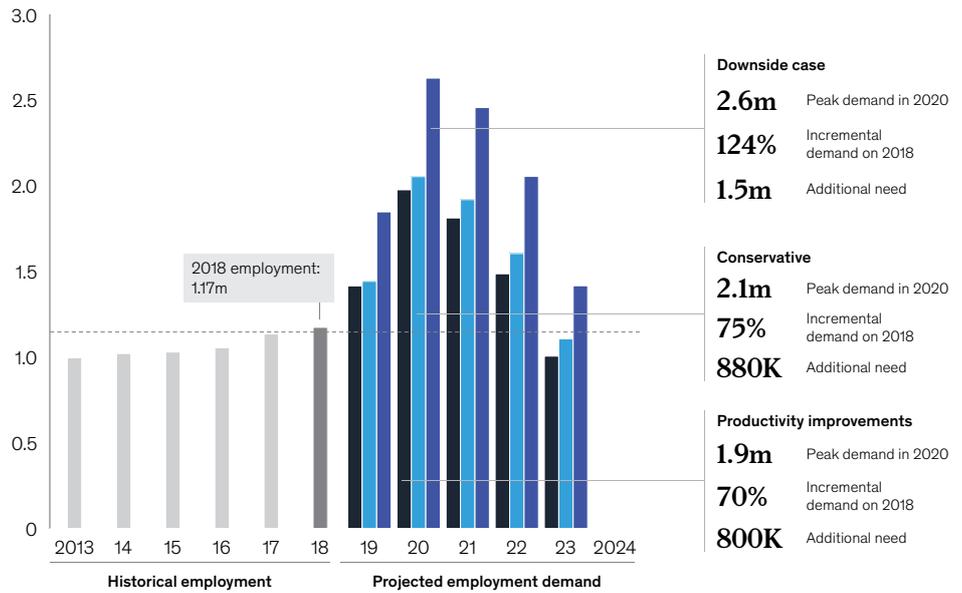
Australia faces significant demand for additional resources for infrastructure construction.

Preliminary High Level Estimate

Estimated employment demand in construction sector

Millions

- 2018 actual productivity +10% productivity CAGR
- 2018 actual productivity
- Last 5 years average productivity



SOURCE: ABS, IPAT, McKinsey analysis

Depending on the scenario and based on high-level analysis, we estimate that Australia could potentially need an additional 260 thousand – 385 thousand infrastructure construction workers over the coming years if the anticipated peak in infrastructure construction spend is sustained. Even under the productivity improvements scenario, Australia may need to find 800,000 additional workers (through recruiting workers from adjacent industries, training new workers or migration) to meet a projected peak demand of 1.9 million (Exhibit 13).

The infrastructure sector in Australia will need additional capacity, the right skills, and the right tools and processes to deliver a program at this scale, while ensuring mistakes from the past are not repeated and value is returned to the general tax-paying public.

Three challenges with meeting the construction demand

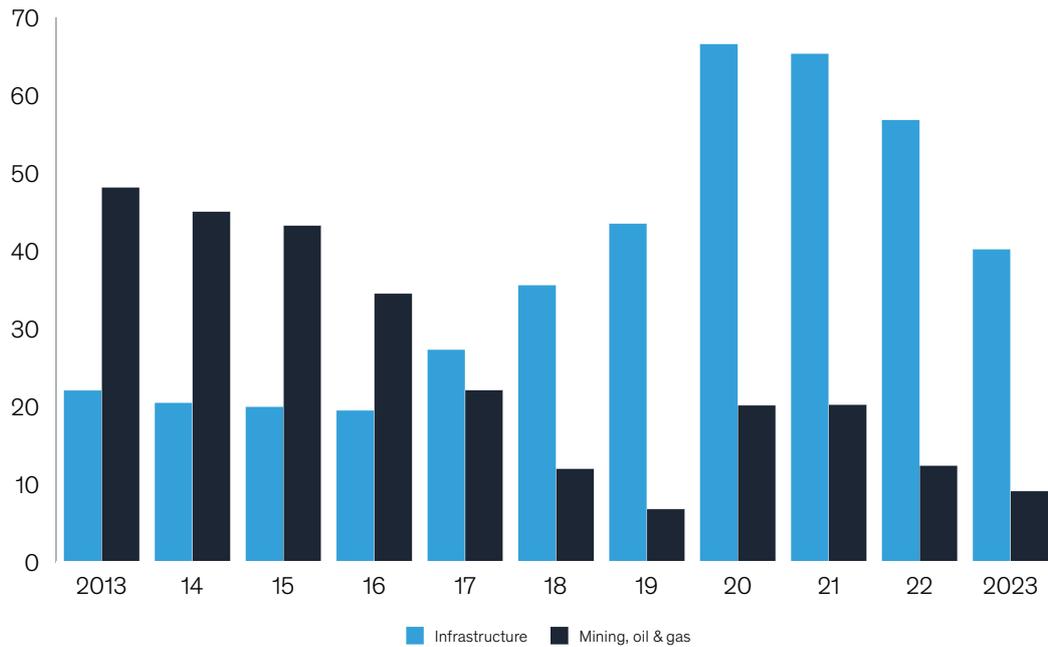
We see a number of unique challenges facing Australia in meeting the infrastructure capability gap in the years ahead:

1. **The need is immediate.** This challenge we face is not in the future—it is happening now. Australia is already on the delivery curve of new infrastructure investment so needs to ramp up capacity and capability in a way that enables the whole sector and value chain. We expect infrastructure spending nationwide to ramp up rapidly to 2020 and 2021, increasing the urgency of the challenge (Exhibit 14).
2. **Mining construction is predicted to ramp up.** While a downturn in the mining boom has created a construction decline in the resources sector over the past five years, we expect it to ramp up again over the next two years. For example, mining and heavy industry construction in Western Australia is expected to grow at 10 percent per annum during 2019–23.³³ This will create even more demand for construction and infrastructure workers as many skills are fungible.

³³ WA Infrastructure Report 2019 by CCA and CCF, BIS Oxford Economics ABS.

Construction in the resources sector is expected to ramp up in the coming two years.

Infrastructure spend per year
A\$ Billions



SOURCE: IPAT

3. **Skilled migration is slowing.** While Australia has historically experienced significant overseas immigration intake relative to its population, skilled migration rates are expected to slow. Recent policy decisions to reduce the annual intake of migrants by 15 percent and tighten visa restrictions³⁴ (reducing the cap from 190,000 to 160,000 from 2019 onwards) will make it harder for the infrastructure sector to employ migrants to mitigate workforce shortages. In combination, these factors will lead to labour inflation if not addressed (see sidebar “Labour inflation during the Australian mining boom”). As demand for labour increases with projected infrastructure spend, labour costs will increase unless supply shortages are addressed.

Labour inflation during the Australian mining boom

If not managed properly, skills shortages can increase the cost of infrastructure.

In the decade to 2012, rising commodity prices led to a boom in the Australian resources sector. During this time, mining companies struggled to recruit enough staff to meet their needs. To address this skills shortage, mining companies offered higher wages to attract workers from other sectors, interstate, and overseas. This increase in earnings eventually spread to other sectors of the economy and between 2003/04 and 2011/12, real wages in Australia increased by 17 percent.

That said, during the mining boom companies could afford to pay more for labour as the cost of hiring an additional worker was lower than the price of the output that the worker could help to produce. However, this is not the case for infrastructure, where wage inflation could lead to cost blowouts and a rise in project costs across the board.

Source: RBA

³⁴ Media release: A plan for Australia’s future population, *Prime Minister of Australia*, 20 March 2019, <https://www.pm.gov.au/media/plan-australias-future-population>.

Three ways to bridge the capability and capacity gap

We suggest that there are three key actions that infrastructure owners and delivery agencies can take to ensure sustainable industry capacity and capability in the years ahead: manage both the demand for workers and the supply.

- **Improve talent retention by reframing the culture of the industry.** Externally and internally, the culture of the infrastructure construction industry is not viewed positively, thereby making it difficult to attract and retain talent. An opportunity exists to reframe and rebrand the industry, highlighting the positive societal impact of delivering and maintaining infrastructure, and the exciting technology opportunities presented by new digital technologies. New behaviours will be required across the industry, requiring stakeholders across the public and private sector to embrace greater collaboration, with less reliance on contract variations and a less litigious approach across the supply chain. There is opportunity for the work required to embed this change to be led across the industry, as well as within individual organisations.
- **Managing the demand for workers can help fill the capacity gap.** This means reducing the overall number of workers required to deliver the infrastructure program. We see three main levers to pull here: adopting new technologies to work more efficiently, reducing process waste, and sequencing works more effectively.
 - *The sector can capitalise on automation opportunities in construction to simplify processes and automate predictable work.* This could potentially affect 44 percent of activities within the sector.³⁵
 - *The sector can manage labour demands by streamlining processes and eliminating work that doesn't add value.* Currently, infrastructure construction involves work that does not add value to final project outcomes. Examples include having multiple consortia completing different designs for the same project as part of the bidding process, or rework due to errors or oversight. Streamlining these processes and reducing error will shrink the work required.
 - *Agencies responsible for infrastructure can work together to sequence work, both within states and across states.* Effective sequencing of work can help to smooth demand for labour and avoid peaks followed by a sharp decline. Smoothing this work over the next 10–20 years will contribute to mitigating labour shortages, while also giving engineering and construction (E&C) providers certainty over the pipeline.
- **Managing the supply of workers will require both short-term and longer-term interventions.** In the short term, the infrastructure sector can manage supply through cross-fertilisation with other sectors. Within the next months, agencies can draw on construction expertise from the resources sector as mining construction experiences a downturn. This is an opportunity to recruit workers with expertise in managing the rapid expansion of capital works at scale. However, this will only offer a short-term solution, as mining construction is expected to grow again from 2020 onwards.

In the medium to long term, Australia can consider developing a nationwide infrastructure sector skills strategy (see sidebar “The UK Transport Infrastructure Skills Strategy”).

This strategy would:

- Build a fact base around the skills, capabilities, and workforce numbers required to satisfy the infrastructure pipeline
- Understand the entry points at which people enter employment in the sector.
- Where shortages exist, identify sustainable strategies to meet the deficit, including:
 - » How to upskill the existing workforce
 - » How to harness mobility to meet shortages
 - » How to increase the talent pool and train the future workforce
 - » Ways to incentivise the private sector to invest to fill the gaps.

³⁵ McKinsey Global Institute Global Automation Impact Model; McKinsey Global Institute analysis

The UK Transport Infrastructure Skills Strategy

In recognition of the transport challenges facing the United Kingdom, in 2017 the UK Government released a Transport Infrastructure Skills Strategy.¹ The strategy defined how the country would develop the workforce required to support its record investment in transport infrastructure. This included supporting jobs, skills, and apprenticeships; maximising productivity of the workforce; and strategies to attract students and workers to the sector.

The UK has since established the Strategic Transport Apprenticeship Taskforce (STAT) to drive the strategy recommendations. STAT is a cross-sector industry body that has responsibility for meeting targets for apprenticeships, sector diversity, and promoting transport as a career. It has established partnerships across the UK infrastructure sector to implement the strategy.

¹ <https://www.gov.uk/government/publications/transport-infrastructure-skills-strategy-two-years-on>.

By developing a national sector skills strategy, infrastructure agencies from different jurisdictions will be encouraged to work together to meet workforce requirements, rather than compete for the same workers. A key component of Australia's infrastructure strategy would need to address training, including setting up "infrastructure academy" programs to develop future workers, as well as relevant managers within government agencies (see sidebar "Best-practice government agencies are investing to ensure their managers are equipped with the requisite know-how").

Best-practice government agencies are investing to ensure their managers are equipped with the requisite know-how

Management skills are crucial to the success of any government program. A study by McKinsey and Oxford University revealed that more than two-thirds of budget overruns in large-scale projects are due to managerial—not technical—shortcomings.

Best-practice government agencies are investing to make sure their managers are equipped with the requisite know-how. The US Office of Multifamily Housing Programs, an agency of the Department of Housing and Urban Development, recently undertook a capability-building program that included a series of process improvements, the introduction of new managerial routines, and intensive coaching on problem-solving skills. The program yielded a reduction of more than 70 percent in the agency's backlog of housing applications and a 35 percent productivity improvement. When Germany's Federal Labour Agency undertook a similar program, the agency's "customers" benefited: their average duration of unemployment fell from 164 days to 136 days. The Swedish Migration Board's capability-building efforts led to a reduction in average processing times from 267 days to 85 days, saving more than \$160 million annually.

Chapter 6: Boosting productivity in project delivery through technology

Technology presents the biggest opportunity to boost productivity in construction, and there are several steps that the private and public sectors can take to lead the sector into the digital era.

Globally, construction is probably the least reliable economic activity, with 98 percent of projects incurring cost or schedule overruns. A survey of large capital investment projects by notable companies in mining, oil and gas, and infrastructure shows that:³⁶

- Average cost increase is 80 percent of original value
- Average slippage is 20 months behind original schedule.

At the same time, lagging labour productivity is a key source of construction challenges (Exhibit 15) globally: labour-productivity growth in construction has averaged only 1 percent a year over the past two decades, compared with growth of 2.8 percent for the total world economy and 3.6 percent in the case of manufacturing.³⁷ Meanwhile, Australian Bureau of Statistics data³⁸ indicate that productivity growth in the Australian construction sector has begun to drop off in the past few years, potentially driven by increased demand and associated market capacity and capability challenges.

Exhibit 15

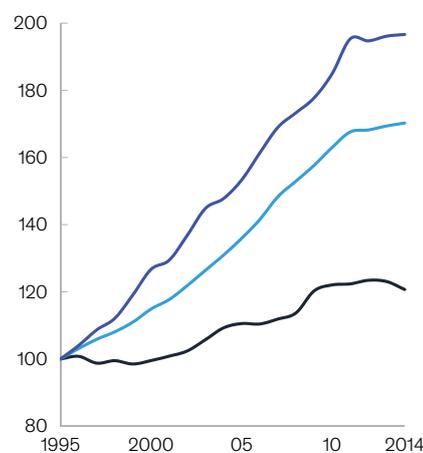
Globally, lagging labor productivity is a key source of construction challenges.

Global productivity growth trends¹

- Construction
- Total economy
- Manufacturing

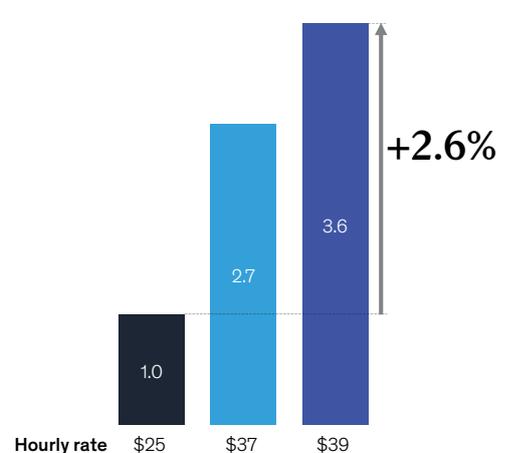
Real gross value added per hour worked by persons engaged, 2005, US\$

Index: 100 = 1995



Compound annual growth rate, 1995–2014

Percent



³⁶ HIS Herold Global Projects database (Nov 19 2013), Companies public annual reports, press releases.

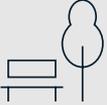
³⁷ McKinsey Global Institute Re-inventing construction.

³⁸ Australian Bureau of Statistics - <https://www.abs.gov.au/ausstats/abs@.nsf/mf/5260.0.55.004>.

McKinsey research shows that improving on-site execution through long-understood (but not always well-executed) practices can help boost productivity by up to 10 percent.³⁹ They include lean construction techniques, performance management, effective project management supported by an active Project Management Office (PMO) and control tower and efficient planning and project controls. These practices remain as important as ever and are fundamental to all efforts in boosting construction productivity.

However, such practices alone have not proven enough. The construction sector will need to increase adoption of technology innovations to make the step change necessary to bridge its productivity gap—McKinsey research indicates that technology is the most promising lever for improving construction productivity, with approximately a 15 percent impact. Construction technology (“contech”) and E&C technology solutions are attracting growing funding globally; overall investment has grown by some 200 percent over the past six years (Exhibit 16). Moreover, the contech space in Australia is also very vibrant, accounting for 8.9 percent⁴⁰ of total venture capital investment in Australia since 2016 (Exhibit 17). In recent years, Victorian public works projects have provided a number of leading examples of the incorporation of BIM and contech solutions, (see sidebar “BIM and contech examples in Victoria”).

BIM and ConstructionTech examples in Victoria

 <p>Victorian Comprehensive Cancer Centre: this \$1 billion facility incorporated BIM.</p>	 <p>Melbourne Park Redevelopment: A.G. Coombs provided 3D drafting and modelling to address design challenges and ensure a trouble-free installation.</p>	 <p>Level crossing removals: BIM has been instrumental in ensuring the complexity of the projects was managed and aligned with just-in-time manufacturing.</p>
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There are several tools that stand-out. The following are a selection of areas, by no means comprehensive, where technology and analytics are poised to make transformational changes to project delivery:

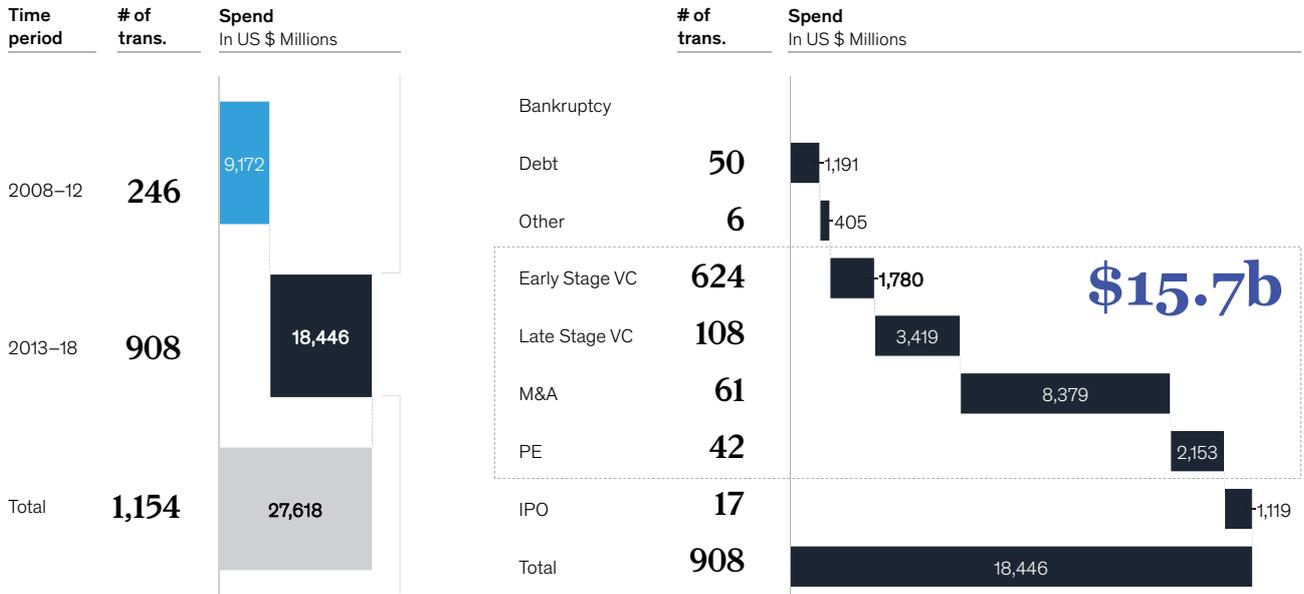
- **Digital twin as-builts.** The “digital twins” approach represents an extension of the use of 5-D building information modelling (BIM) concepts to advance from a traditional design to a live digital update of as-built progress. Digital twin applications utilise an integration of 3-D models generated by drone imagery and other reality-capture technologies such as satellite imagery and LiDAR, combined with live key performance indicators that are monitored using IoT sensors. This creates an exact digital replica of a project’s physical reality, allowing users to incorporate as-built data into 3-D models for automated, real-time progress updates, while facilitating virtual site inspections that utilise mixed reality to combine 3-D design with as-built configurations. This improves safety by reducing physical presence on site, improves connectivity between site and office, and reduces time in decision-making cycles in schedule and budgeting to shift from monthly reviews to daily optimisation.

³⁹ Reinventing construction: A route to higher productivity, *McKinsey Global Institute*, February 2017, McKinsey.com.

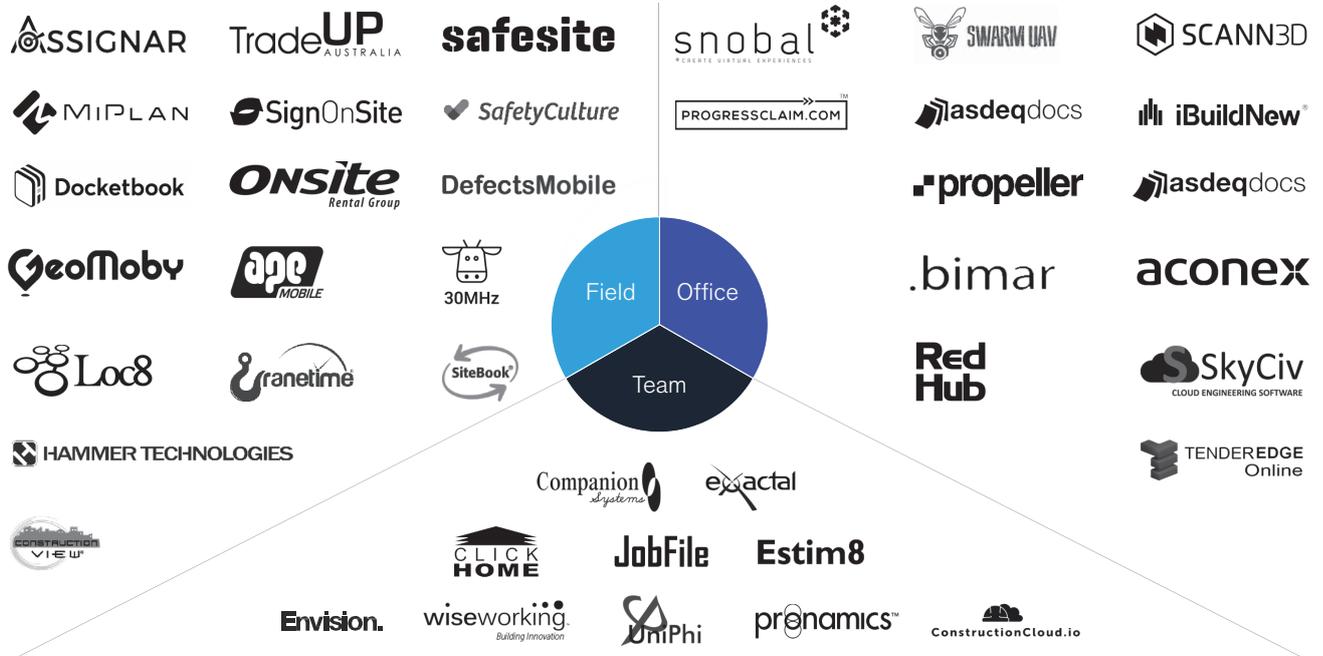
⁴⁰ Digital Foundations, How Technology is Transforming Australia’s Construction Sector, *StartupAus* report

Investment in constructiontech has grown by some 200 percent globally.

Investment—over time and by type



The Australian construction technology ecosystem is active with a growing range of solutions being developed.



SOURCE: StartupAus report on Digital Foundations, How Technology is Transforming Australia's Construction Sector

- **Use of artificial intelligence and advanced analytics in design and schedule optimisation.** In the long-term, AI and analytics have numerous potential use cases in E&C. A few examples we currently see include using machine learning and reality capture to compare in situ field conditions with plans; optimising schedules to sequence tasks and hit target deadlines and provide real-time guidance on divergences from blueprints to predict and correct issues; and in the longer-term, data input of multiple separate design packages that could feed into an AI design program to select the appropriate design.
- **Use of technology in contract assurance.** We have seen companies save up to 16 percent on contract cost, in terms of measurement and verification, with the use of drones. This approach saved on labour, but also on daily interest payments, as this approach involved less working capital for cheaper up-front price.
- **Use of drones and IoT to improve safety outcomes on site.** Examples include real-time monitoring of hazards with alerts (such as a labourer walking beneath a crane) together with transparency into whether the site is being built to an adequate safety standard.
- **Use of digital tools in performance management and in establishing a project production system.** Standardisation of work on site can improve cost and time performance, increase senior management visibility, and reduce instances of project “blow-outs” such as delays and budget overruns. These principles, contained within lean manufacturing, can be further enhanced with digital construction techniques across four main areas: using IoT to collect data on all man and equipment movements to provide full visibility of progress and optimise efficiency; utilising a “digital control tower” to monitor real-time performance management; use of on-site robotics (for example, employing autonomous vehicles to standardise repetitive tasks); and harnessing remote connectivity to facilitate better information flow (for example, a virtual site walk-through in current, as-built condition).
- **Using modularisation, off-site manufacturing, and machinery to create a manufacturing-based approach to construction.** Parts of the construction industry are moving toward a manufacturing-like system of mass production, relying on prefabricated, standardised components that are produced off-site. While this is less applicable in transport infrastructure, relative to real estate, given the inherently lower level of homogeneity in the product, there are some applications within transport infrastructure (for instance, deck-laying machines called launch girders used for constructing Dubai Metro’s pre-cast and modular viaduct segments in place, on top of pre-cast piers and pier heads) as well as many applications in construction of related areas of transport infrastructure (such as airport terminals and rail passenger stations). Our research finds that consistent use of these techniques, on projects where they are economically feasible, could boost the sector’s productivity substantially. Example use cases include:
 - Construction robotics such as bricklaying or welding robots, similar to self-driving heavy machinery in mines to make construction safer, faster, and more affordable
 - Off-site prefabrication of modular elements, or complex re-bar fabrication to turn a 3-D model into a prefabricated building component—recent modular projects have already established a solid track record of accelerating project timelines by 20 to 50 percent⁴¹
 - The use of exoskeletons and wearable robotics to harness the strength of robotic arms
 - 3-D printing of long-lead components such as joints.

⁴¹ Modular construction: From projects to products, *McKinsey & Company*, June 2019, <https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/modular-construction-from-projects-to-products>.

There are six things government authorities can consider going forward to lead infrastructure construction and delivery into the digital era

In this context, project sponsors will play a critical role in enabling technology adoption by the sector. Here are the six things Australian authorities can do to lead infrastructure construction into the digital era:⁴²

- **Collect and “own” data**—big data is a significant enabler for digitisation; authorities can access and collect data about end users and customers.
- **Set bold aspirations**—at the outset, governments can articulate bold aspirations for the adoption and use of technology in public-sector projects; beyond increasing awareness, such public aspirations demonstrate the priority given to developing a more efficient construction industry through broader deployment of new technologies.
- **Create meaningful incentives**—governments can also use financial resources and tendering processes to create meaningful incentives for construction companies; for example, public grants could be offered to help companies adopt technologies that aid in-project design and execution. Further, public contracting agencies can insist that successful bidders incorporate digital collaboration tools into publicly owned projects. For example, the Tennessee Department of Transportation recently announced it will require prime contractors and designers to use construction productivity software on all its projects, beginning with March 2019 contract awards.
- **Manage risk**—in addition to creating meaningful incentives to spur adoption, governments can help reduce the barriers and risks that are unique to these emerging technologies; for example, procurement or acquisition regulations often place significant emphasis on a contractor’s past performance in future source selections.
- **Ensure transparency**—measures to increase transparency around costs and progress of public projects can be enhanced by digital technologies that provide real-time progress information; in turn, increased transparency creates pressure to complete projects on budget and on time, and this becomes easier when new technologies are deployed.
- **Build capabilities**—as with most industries, the construction sector will struggle to find the talent needed to use new technologies effectively, but governments can play a dual role in helping to meet this challenge: investing in training programs not only builds needed capabilities but also provides new opportunities to workers displaced by these technologies.

⁴² Governments can lead construction into the digital era, *McKinsey & Company*, April 2019, <https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/governments-can-lead-construction-into-the-digital-era>.

Takeaways for key stakeholder groups

In this report, we have purposefully described the challenges and opportunities for the infrastructure sector as a whole. However, we recognise that each stakeholder group has the ability to influence different elements of the infrastructure planning, design, and delivery value chain. Below we set out our thoughts on some of the key takeaways and initiatives for government, investors, and contractors.

Government. The Commonwealth, state, and local governments are the ultimate funders of public infrastructure and accountable to residents for timely, effective, and affordable provision. They also set the policy, legal, and regulatory framework within which investors and contractors operate. Given the scale of Australia's infrastructure portfolio and the size of the gap, governments face a huge challenge as they integrate across the various industry stakeholders to deliver infrastructure on time and to budget. To address these challenges, we believe there are a number of areas where government can consider innovation options to lead Australia's infrastructure agenda:

- **Publish an integrated vision for how technology will shape the way that people and freight move around a city.** This will involve making purposeful choices around Australia's future target state in relation to mobility, smart cities, and the implications of automation. For such a vision to be practical, it will need to capture and articulate the implications of these trends and resulting choices for the allocation of capital by asset class/mode (for instance, rail versus road) and investment category (mandatory versus discretionary, further subdivided into strategic, capacity expansion, or provision of additional population coverage). We should note that this approach requires a more holistic view of infrastructure provision.
- **Identify and address the major policy enablers and barriers to the adoption of infrastructure innovations.** The most difficult aspect of this will be to manage the transition towards the future state enshrined in the vision. For example, one of the primary rate-limiting factors in the adoption of autonomous vehicles will be how laws adapt to reflect inherent risks (such as responsibility for fatal accidents). Another example, in the context of smart cities, is how well residents' data privacy concerns are addressed and to ensure they do not feel that big business is taking advantage of them. In certain cases, government will need to set standards that mandate the adoption of technologies in the delivery of major infrastructure assets—for example, 5D BIM.
- **Rethink the way projects are prioritised and selected.** This will involve developing the capability to perform rapid options analysis, while reorienting formal business-case analysis to avoid simplifying projects to single (potentially misleading) metrics, and to focus on scenarios that take future disruptions into account. It will also involve applying behavioural science to debias decision making, for example through conducting robust pre-mortems and encouraging diversity of thought.
- **Promote the development of capabilities within the “owner’s team”.** Government can consider how to develop the necessary internal capabilities to manage the portfolio of infrastructure megaprojects through their lifecycle. This is a non-delegable set of capabilities driven by government's unique position as the integrator and ultimate owner of all risk (regardless of contractual mechanisms). It will include working with industry to conduct an iterative, collaborative design-to-value process for all projects, adopting an agile approach.

- **Build industry capability, capacity, and competition.** This will involve moving away from traditional contracting, risk transfer, and tendering models to create the conditions for new market entrants. It will also mean adopting innovative practices such as collaborative contracting and potentially even setting up panels of qualified contractors to enable longer-term private-sector investment in capability development. Agencies responsible for infrastructure can work together to sequence work, both within and across states, helping to mitigate labour shortages while also offering contractors more certainty over the pipeline. To address short-term skills shortages, governments could draw on underutilised construction expertise from the resources sector. In the longer term, governments should consider developing a national sector skills strategy and identify sustainable strategies to address the deficit.

Investors (private and public sector). In recent years, investors have competed down infrastructure asset yields as they seek long-term homes for capital. Now, however, they face huge uncertainty as disruptive technologies (for example, autonomous vehicles) render traditional investment cases and contracting models (such as 30-year concessions) inadequate—especially where demand risk is taken into account. Investors can consider how to:

- **Apply design-to-value using an agile approach.** Investors (both government and private institutions) are in a unique position to bring together owners/developers, designers, and builders of infrastructure megaprojects to fundamentally reform traditional value-engineering approaches. By convening collaborative, multidisciplinary agile teams of dedicated professionals (“squads”), driving at pace through a series of sprints to rapidly iterate the design, investors can force trade-off decisions and significantly improve return on capital.
- **Actively assess the impact of disruptive trends on infrastructure demands and usage.** This will involve building an assessment of real-world future scenarios into the investment assessment and prioritisation process, these scenarios being based on the evolution of disruptive trends such as the future of mobility, smart cities, and automation.
- **Proactively consider investing in new asset classes created by technology.** There is high demand for potentially attractive new asset classes created by infrastructure technology trends. Examples include electric vehicle charging points and smart-city sensor networks. Investors able to understand the fundamentals and “tipping points” for these new asset classes will achieve a substantial first-mover advantage and deliver outperformance.

Contractors. While contractors have the potential to benefit from unprecedented demand, they currently face the very real prospect of a “profitless boom” caused by high transaction costs, staff churn, industry fragmentation, productivity stagnation, increased contractual and technical risk, and challenges in accessing skilled labour. There is a huge prize for those that can crack the productivity challenge and act as a thought partner to government. Aspects to consider include:

- **Championing innovations to create a step-change in productivity.** Given the scale of private infrastructure investment, Australian contractors have the opportunity to lead the world in productivity improvements driven by technology. This will require them to set a technology vision and aspiration that supports their productivity ambitions; identify and quantify the technology “use cases” to unlock value; and commit to a roadmap that balances meaningful investment in core enablers (such as data analytics and multi-speed IT) with a phased approach that builds confidence. Capturing this potential will also require an intensive focus on non-technology disciplines (for example, lean construction) to ensure change is achieved in the front line.
- **Invest in required skills and competencies.** Contractors will need to develop the requisite internal capabilities to plan and deliver a portfolio of infrastructure megaprojects from conception and selection through to completion, incorporating the relevant process, technology, and business partnering skills (including agile and DTV) to drive enhanced performance and productivity.

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