

# Flexible cities

The future of Australian  
infrastructure

Written by

The  
Economist

INTELLIGENCE  
UNIT

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## ABOUT THIS REPORT

*Flexible cities: The future of Australian infrastructure* is a report written by The Economist Intelligence Unit (EIU) and sponsored by Salini Impregilo. Drawing on global trends and international best practice, it considers how Australia can develop the capabilities to both plan and build more flexible and adaptive infrastructure that can serve the successful expansion of its cities.

This report is based on in-depth desk research and interviews with stakeholders and experts from government, consultancies, universities and infrastructure organisations across the country. The EIU would like to thank all participants for their time and insights. Those interviewed were:

- **Steve Abson**, CEO, Infrastructure Association of Queensland
- **Kylee Anastasi**, Partner, Infrastructure and Urban Renewal, PwC Australia
- **Peter Aubusson**, Professor of Education, University of Technology Sydney
- **Catherine Ball**, Founder and Executive Director, World Of Drones Education, Co-creator and technical convenor, World Of Drones Congress
- **Ghassan Beydoun**, Deputy Head of School (Research), Information, Systems and Modelling, Faculty of Engineering and Information Technology, University of Technology Sydney
- **Peter Colacino**, Executive Director, Policy and Research, Infrastructure Australia
- **Phil Davies**, Chairman, SMART; former Chief Executive, Infrastructure Australia; and former Director, Transport for London
- **Adrian Dwyer**, Chief Executive Officer, Infrastructure Partnerships Australia
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- **Tim McMinn**, Senior Manager, PwC Australia
- **Harry Quartermain**, Principal, Planning, Ethos Urban

# FLEXIBLE CITIES

## THE FUTURE OF AUSTRALIAN INFRASTRUCTURE

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- **Glen Searle**, Adjunct Associate Professor in Planning, University of Queensland
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- **Kerryn Wilmot**, Research Principal, Architect Institute for Sustainable Futures, University of Technology Sydney

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## EXECUTIVE SUMMARY

Cities are struggling to keep up with the changes we see around us—from new technologies that are changing how we live and work, to unprecedented population growth or the impacts of climate change. These pressures demand new thinking in infrastructure. In much of the world we have historically planned, designed and built infrastructure over decades, often with hundred-year lifespans in mind. Many infrastructure projects take years to get off the ground, such that by the time they arrive they risk serving yesterday's needs.

As this report finds, cities need smarter and more flexible infrastructure to address these challenges—infrastructure that can make better use of existing space and resources, and that can adapt in accordance with uncertain, fast-moving future realities.

The idea of 'flexible' or future-proof cities is becoming more important. Imagine a roadway that works for today's vehicles as well as tomorrow's autonomous cars, an energy system that can provide reliable power despite spikes in usage (such as those that may come from greater adoption of electric cars), pylons that are mindful of overhead drones, a building that transforms depending on needs of its inhabitants, or an autonomous rail system that can double its capacity simply through changes to its operating algorithms.

Delivering infrastructure that is more responsive and flexible to future needs requires technological innovation as much as new approaches to planning, financing and procurement.

In this report, The EIU investigates the challenges facing cities and urban infrastructure in the near future, and the global trends and innovations in infrastructure that will be crucial in response. With an eye to international best practice, it focuses on the challenges and opportunities pertinent to Australia. Here, major cities are expected to face significant population growth forecasts that call into question their ability to continuously provide a high quality of life for their citizens. Challenges pertain to both meeting infrastructure needs, and delivering solutions, through effective planning, financing and collaboration, in time and on budget.

The key findings of the research include:

- **Australia is experiencing a number of growing pains.** Population growth in cities is a universal trend—urban population is expected to rise by two-thirds by 2050 globally—but it is particularly acute in Australia, where cities must meet double or greater user demand while also working to achieve the global targets set by the Paris Agreement and Agenda 2030. Such growth challenges the capacity and sustainability of cities' infrastructure and the networks that connect them. Planners must also reckon with an ageing population, deteriorating infrastructure, adverse environmental change and evolving working patterns, altering the dynamics of how people operate in and navigate cities. A failure to respond to these challenges could result in declining economic productivity and threats to the quality of life for which Australian cities are renowned.
- **To meet future demands, infrastructure builders across the globe are considering how they can expand the capacity of existing infrastructure and bolster the flexibility of new works.** Updated networks like roads, railways and pipelines often need to accommodate twice their

original usage demand without changing their physical footprint. The effective adoption of digital technology will be key to this transformation, such as updating metro systems with driverless trains and automatic controls, informed by large amounts of real-time data, to allow a more efficient use of capacity. Water and energy supply systems must also prove reliable and resilient in the face of natural disasters, shifts in market prices (such as oil or gas price shocks) or changes to supply sources (backups for solar generation, for example).

- **New technological techniques and applications can help builders work more quickly, safely and cost-effectively.** The design, construction and maintenance of infrastructure projects are increasingly driven by digital technologies, unlocking cost and time savings in building roads, railways and entire city centres. The cost and energy required to build with the highest safety margins could be reduced by remote monitoring through embedded sensors. Efficient, low-impact construction techniques will be important to reduce the disruption that construction and repairs have on metropolitan areas, too.
- **Stakeholders are increasingly reliant on data to plan, build and optimise projects.** Data generated by citizens and connected infrastructure are increasingly critical in delivering and operating smarter cities. Governments and infrastructure providers increasingly benefit from adding these data to their modelling and scenario planning. Open data can also allow citizens and third parties to solve problems or develop new applications that benefit all, from crowdsourcing potholes or reporting crime, to building new navigation apps. Australia's state and federal governments, citizens, and commercial partners are still grappling with data ownership issues, but all are working to address the challenges.
- **Mature financing and procurement practices help Australia attract international investment.** Attractive markets and clear rules encourage international competition for infrastructure procurement. Indeed, many of today's projects are contracted to international players who bring advanced, ambitious and sustainable proposals to government. And as demand for more advanced, flexible projects rises, players are increasingly presenting envelope-pushing approaches to win bids.
- **Collaboration between governments, universities and commercial players is increasing, sparking innovation.** Universities are playing a larger role in the advancement and application of infrastructure technology by partnering with private companies and government. New forms of collaboration are also more apparent among federal, state and local governments, and between governments and the private sector, potentially easing the problems posed by the historically disjointed nature of decision-making and long-term planning on major infrastructure.
- **Australia has a strong record of robust infrastructure investment and could be a model for other countries.** Its leaders, institutions and businesses have identified the urgency and importance of responsible and smart infrastructure initiatives. As a result, Australia is well placed to wrestle with the challenges it faces, and, as it navigates infrastructure challenges earlier and with greater urgency than some other countries, could be a model for how other countries—in the OECD and in Asia-Pacific—build smarter, more flexible, next-generation infrastructure in their cities.

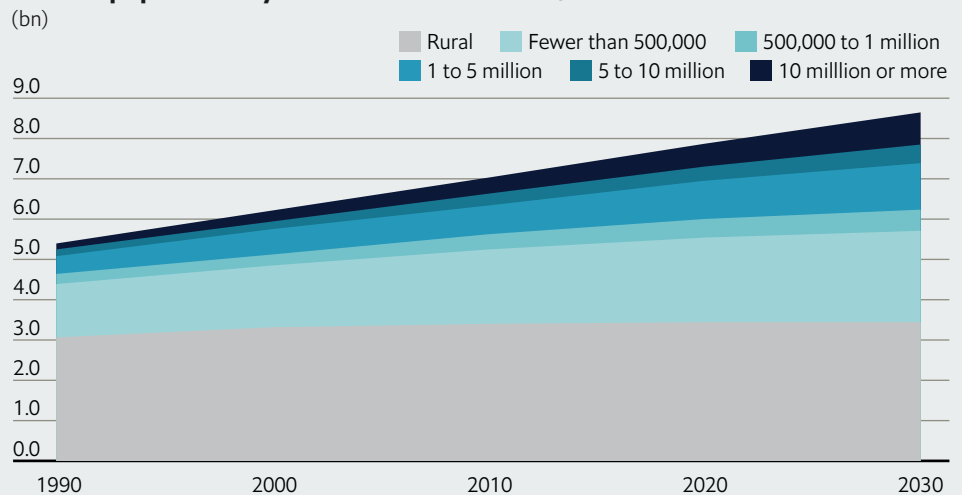
## Chapter 1 INTRODUCTION

The future is an urban one. Today, just over half of the global population lives in urban areas, a proportion expected to rise, through overall population growth as well as through migration from rural areas, to over two-thirds (68%) by 2050—an addition of 2.5 billion people to our cities and towns.<sup>1</sup>

The opportunities afforded by population growth to cities are great. Cities are economic engines and centres of business, culture, knowledge and innovation. Labour productivity tends to be much higher than in rural areas, and urbanisation has historically been strongly correlated with economic growth, education and entrepreneurialism. In 2015 approximately 85% of global GDP was generated in cities.<sup>2</sup> Population growth brings an expanded workforce, more customers for local businesses and a larger tax base, with additional revenue to be invested in roads, public transit, parks and schools.

**Figure 1: One in five people worldwide lives in a city with more than 1 million inhabitants, a number projected to grow to 28% by 2030**

### World's population by size class of settlement, 1990-2030



Source: UN Department of Economic and Social Affairs.

However, if cities have not appropriately planned and prepared for it, such rapid growth can push critical infrastructure, social services and natural resources to their limits. Many countries will face challenges in meeting the needs of their growing urban populations. As cities grow larger in scale and population, services risk fragmentation and inequalities can arise in access to housing, healthcare, employment, education, policing and transport.

This report will investigate how sociodemographic, technological and environmental changes such as these pose challenges for urban infrastructure development (Chapter 2), before drawing on some examples of infrastructure innovation that will be key in addressing them (Chapter 3). Infrastructure

1. UN Department of Economic and Social Affairs, World Urbanization Prospects 2018, <https://population.un.org/wup/>  
2. The New Climate Economy, Seizing the Global Opportunity, <https://newclimateeconomy.report/2015/>

challenges are only in part design and engineering problems: financing, procuring and effectively collaborating to deliver complex infrastructure projects in time, on budget and with minimal disruption are arguably much greater challenges, and these considerations will be the focus of the final chapter. The rest of this chapter demonstrates the growing importance of flexibility, in both stakeholders' approach to development and in physical infrastructure itself, and the pertinence of these issues to Australia in particular.

### ***Building a city to meet tomorrow's demands***

Modern societies depend on effective, reliable infrastructure, and cities will not thrive if their infrastructure is not capable of adapting to future needs. It is no surprise then that higher sustainability standards are increasingly being built into regulatory frameworks, and promoted within stringent environmental legislation, building standards and energy performance criteria.

But building to higher standards is not enough to meet the challenges that come with urban growth forecasts. Planners and designers must also focus on boosting resilience of existing infrastructure and designing new buildings capable of responding to technological and environmental shifts and the changing demands of citizens.

Further challenges accompany urbanisation and population growth, not least the effects of pollution on air quality, and the uncertain impacts of climate change, including extreme weather events such as floods and destructive storms. Ageing infrastructure doesn't just reach capacity or crumble with age, but can fail to adapt to changes in how we live and work: most modern cities have been built around cars, for instance, and physical retail spaces. Today's city dwellers increasingly shop online and expect ever faster delivery times. To meet their needs, cities need the support of last-minute distribution centres, out-of-town warehouses, and delivery capacity—be it by bicycle, van or drone.

Consequently, new infrastructure and infrastructure upgrades are often approached with flexibility in mind. The mission of flexible building is to maximise the function of the old critical infrastructure, and to design new projects that are adaptable, transformable or convertible for future use. In this way, future infrastructure is fit for purpose under multiple plausible future scenarios, including economic, technological, environmental and demographic shifts.

Flexibility takes many forms. It might pertain to movable physical parts and multi-use spaces—such as the Shed, a new cultural institution in New York City with adaptable and expandable venues for housing art and cultural exhibits<sup>3</sup>, or the Tonsley Innovation District in Adelaide, Australia, where an automotive manufacturing site has been transformed into a centre for innovation composed of moveable, modular office space.<sup>4</sup>

Flexibility can also refer to changes in the technology and coding and even energy supply that powers the infrastructure. For example, integrating the needs of autonomous cars and drones on existing roadways, adapting traditional oil and gas energy systems for more alternative energy sources, or converting water systems to be more disaster-resilient in the event of intense periods of drought and floods driven by climate change.

3. <https://www.hudsonyardsnewyork.com/discover/the-shed/>

4. <https://tonsley.com.au/>





The Shed, a cultural venue scheduled to open in 2019 in New York, is built with flexibility in mind. Multiple spaces can be reconfigured to accommodate virtually any cultural discipline, present or future, Dan Doctoroff, chairman and president, told reporters. “Our basic view—whether it’s with respect to culture or to city building—is [that] nobody’s smart enough to predict the future. So you cannot plan to detail

what’s going to happen. Instead what you can do is, create the infrastructure. That might be physical, it might be digital, might be some ground rules, et cetera, that enable people to project their own ideas and innovations onto it as taste, technologies, trends begin to change. And I think that is a very different notion of a cultural institution as well as city building.”<sup>5</sup>

Image: Diller Scofidio + Renfro in collaboration with Rockwell Group

Cities can also benefit from technological advances long associated with the vision of the “smart city”, where real-time streams of data on city health and activity constantly optimise services and inform their design. These data-rich landscapes empower officials and citizens with means to deal with the fragmentation of services and shifts in supply and demand. Ambulances can be redirected when one hospital is at capacity, or garbage pickup rerouted when bins are full or to lessen impact on congestion and air pollution. Adoption of such ideas has in practice so far been slow and limited, but new infrastructure can be built with these ideals in mind.

Best practices for flexible, future-proof building are unfolding around the globe. The Netherlands, for example, has been ranked the most prepared nation for autonomous vehicles because of the country’s well-maintained highways, strong telecom infrastructure and government support for testing on public roads.<sup>6</sup>

5. Freakonomics, How to Build a Smart City, <http://freakonomics.com/podcast/dan-doctoroff/>

6. KPMG, 2018 Autonomous Vehicles Readiness Index, <https://home.kpmg.com/xx/en/home/insights/2018/01/2018-autonomous-vehicles-readiness-index.html>

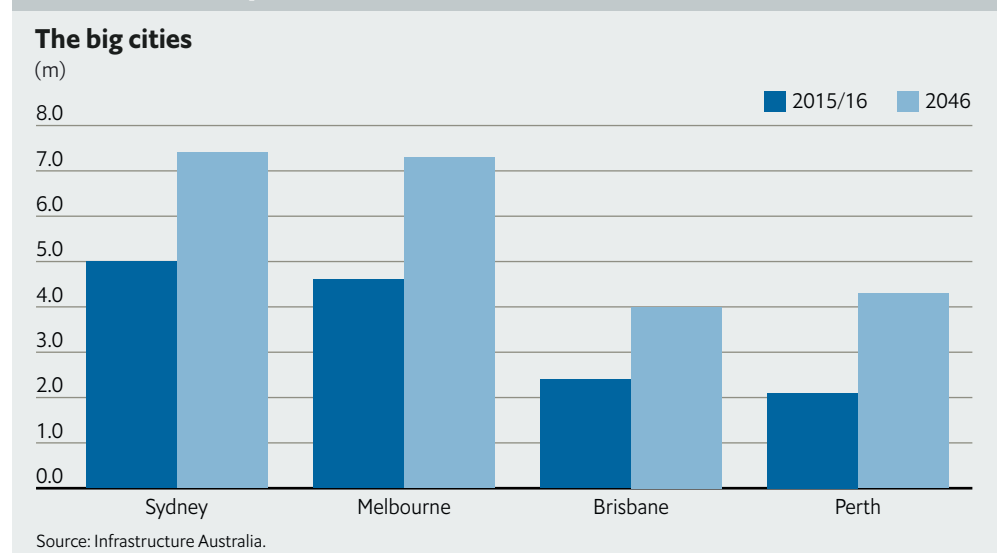
### **Australia’s forecast**

Australia has particularly pressing infrastructure challenges, given its demographic trends. The country has one of the highest population growth rates among medium and large OECD countries. Overall

population has increased by 40% since 1990 and is forecast to increase by another 40% by 2040. More than 75% of that growth comes from just four cities: Sydney, Melbourne, Brisbane and Perth, which already account for 58% of Australia's population.<sup>7</sup>

Growth is increasingly putting pressure on Australian cities—most immediately on transport infrastructure but also schools, hospitals, green space, air quality and the affordability of housing.

**Figure 2: Projected population growth for Australia's biggest cities. More than 75% of the country's overall population growth in the next 20 years is forecast to come from these four cities**



“That is one of the biggest challenges that Australian cities are grappling with right now,” says Adrian Dwyer, CEO of Infrastructure Partnerships Australia. “People forget that Australia is one of the most urbanised countries on Earth. Most Australians live in cities, and because the footprints of those cities are very large, it is definitely an urban society and a major urban metropolitan society as well.”

Australian cities are challenged not just by increased density but sprawl, having traditionally grown outwards into greenfield land.<sup>9</sup> However, as the footprint of Australian cities expands the provision of services becomes increasingly challenging. If the focus doesn't decidedly shift to managing an increase of density instead of increasing sprawl, Australian cities are in danger of acquiring many of the negative aspects of large cities without the economic benefits of agglomeration.

Despite these pressures, there are clear upsides to Australia's urban population growth. According to Peter Colacino, executive director of Policy and Research at Infrastructure Australia, Australia views these changes foremost as opportunities: “Growth is absolutely a positive for the economy and the country, but we need to start to wrap our heads around the challenges that growth also brings.”

7. Australian Bureau of Statistics, Regional Population Growth, Australia, 2016-17, <http://www.abs.gov.au/ausstats/abs@.nsf/mf/3218.0>

8. The Australian, Plan now or quality of city life will decline, says Infrastructure Australia, <https://www.theaustralian.com.au/national-affairs/plan-now-or-quality-of-city-life-will-decline-says-infrastructure-australia/news-story/cd780088976dbd5b087535efdf67cfb9>

9. Australia State of the Environment, Increased urban footprint, <https://soe.environment.gov.au/theme/built-environment/topic/2016/increased-urban-footprint>

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## THE FUTURE OF AUSTRALIAN INFRASTRUCTURE

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Australia has a high standard of living that it is working hard to protect. Its cities have dominated The Economist Intelligence Unit's annual Liveability Index since its establishment in 2007<sup>10</sup>. Until slipping to second place in 2018, Melbourne held the number one spot for seven consecutive years.

Now the country is grappling with how to transition the world's most liveable cities—which have managed mobility and infrastructure well with populations of 4m-5m, historically a sweet-spot for liveability—to cities that accommodate twice as many people within largely the same footprint, while maintaining a similar (if not superior) quality of life.

Australia is already working to meet these challenges. Investment in infrastructure is at record levels, and many cities already demonstrate envelope-pushing innovations. Although these successes should be celebrated, more needs to be done to ensure the sustainability of the country's cities. So far, Australia has only scratched the surface.

10. The Economist Intelligence Unit, The Global Liveability Index 2018, <https://www.eiu.com/topic/liveability>

## Chapter 2

# PRESSURE POINTS

As cities grow denser and urban populations rise, approaches to infrastructure must adapt and city planning be rethought with greater capacity in mind. This chapter explores some of the infrastructure pressure points for global, and particularly Australian, urban development. These include congestion, antiquated infrastructure and the risks inherent in addressing today's needs while anticipating the needs of the future.

### *Preparing for the unknown*

There is no reliable answer to how climate change or technologies such as drones, driverless cars or the advanced monitoring of city infrastructure could transform buildings, roadways and population flows. Flying cars, for instance, might be impractical in many respects,<sup>11</sup> but test flights in Dubai and New Zealand are already underway, and investment is growing, including from big names such as Airbus and Uber. How do cities plan for the possibility of such technologies becoming a commonplace reality, and fit them into existing plans?

"Australia and other countries are struggling to figure out what future mobility will look like," says Simon Washington, professor and head of civil engineering school at the University of Queensland (UQ). "The lifecycle of major infrastructure is long, so a significant challenge right now is developing a long-range strategy or vision that is and will be compatible with project lifecycles. The problem is that I don't think anyone has a solid answer given the pace of disruption."

"There's a developing sympathy among people in Australia for the fact that technology can sometimes render what you're doing obsolete nearly as it's completed," adds James Hutchin, an advisor to Flinders University in Adelaide. "And when it takes multiple years to get a project completed, the odds of actually getting a return on that project, because it had a technological lifespan that was useful, are dramatically reduced."

Phil Davies, former chief executive of Infrastructure Australia and former director of Transport for London, adds that certain things can be predicted with more confidence. "One would be autonomy and electrification of vehicles. These trends are likely to have an impact, such as less need for parking spaces, so that, as a direct result, more green space could emerge."

In an assessment of twenty countries' perceived readiness for autonomous vehicles, conducted by KPMG, a consultancy, Australia ranked 14th (see figure 3). Several Australian cities are hosting trials for AV; the New South Wales government, for instance, has announced a AU\$10m fund to encourage governments, universities and the private sector to work together to develop and test driverless technologies throughout the state. However the researchers found the country lacking in technology and innovation. On infrastructure, Australia receives middling ratings for the quality of its roads, availability of 4G and electric charging stations<sup>12</sup>

11. Project Syndicate, Flights of Unmanned Fancy, <https://www.project-syndicate.org/commentary/drone-taxis-uavs-urban-mobility-by-carlo-ratti-2017-09>

12. KPMG, 2018 Autonomous Vehicles Readiness Index, <https://home.kpmg.com/uk/en/home/insights/2018/01/2018-autonomous-vehicles-readiness-index.html>

The incorporation of flexibility should take place early in the planning phases, suggests Mr Davies. For every city, future-proofing will vary depending on the forecasted risks.

### Driving ambition

**Figure 3: A readiness index from KPMG finds that the Dutch lead the way in preparing for autonomous cars, while Australia comes 14th out of 20 countries assessed.**

Overall rank	Country
1	The Netherlands
2	Singapore
3	United States
4	Sweden
5	United Kingdom
6	Germany
7	Canada
8	United Arab Emirates
9	New Zealand
10	South Korea
11	Japan
12	Austria
13	France
14	Australia
15	Spain
16	China
17	Brazil
18	Russia
19	Mexico
20	India

### Congestion

13. INRIX, Global Traffic Scorecard, <http://inrix.com/blog/2017/02/congestion-is-growing-so-how-do-we-tackle-it/>

14. CityLab, Traffic's Mind-Boggling Economic Toll, <https://www.citylab.com/transportation/2018/02/traffics-mind-boggling-economic-toll/552488/>

15. Bureau of Transport, Infrastructure and Regional Economics, Traffic and congestion cost trends for Australian capital cities, [https://bitre.gov.au/publications/2015/is\\_074.aspx](https://bitre.gov.au/publications/2015/is_074.aspx)

16. Austroads, Congestion and Reliability Review, <https://www.onlinepublications.austroads.com.au/items/AP-R534-16>

Worldwide, drivers spent 9% of their driving time in 2016 stuck in traffic. The consequences of this are well documented, including productivity losses and increasing carbon emissions, inequality and social division. These effects are only worsening as urbanisation rises.<sup>13</sup>

To keep people moving, cities around the world are testing new measures that adapt existing roads. Examples include real-time traffic sensors in London that optimise traffic light timing to reduce delays, dynamic road pricing in Stockholm, and new public cycling systems in Hangzhou. Lessons might also be taken from Singapore, where the Ministry for Transport is planning to make three districts ready for autonomous vehicles by 2023.

Although Australian cities are not among the world's busiest,<sup>14</sup> congestion nonetheless costs the Australian national economy AUD\$16.5bn a year in lost productivity, a figure set to rise to AUD\$35bn

by 2031 if robust measures aren't taken, according to the Bureau of Transport, Infrastructure and Regional Economics.<sup>15</sup> Congestion is worst in Sydney and Melbourne, Australia's biggest cities, where road users have to plan for 50% more time per journey during peak hours.<sup>16</sup>

Notably, in Infrastructure Australia's 2018 annual Infrastructure Priority List—an independent view of the projects required to meet Australia's growth challenges around infrastructure—the need to address urban congestion features in every one of its top six priorities.<sup>17</sup>

### USER FUNDING MODELS IN DISRUPTION AND DEBATE

Because technology is transforming mobility behaviour, governments are continuously forced to evaluate the way in which user charging can be used to manage demand and pay for upkeep and development. Reform is imminent.

“How to finance transport going forward is a huge problem for Australia, as it is for much of the world,” adds Mr Washington. “Most countries rely heavily on fuel excise tax to fund transport. As we transition to a different mobility world with much cleaner and fewer vehicles through sharing, transport funding models all around the world are going to be upended.”

In a future scenario in which Australians predominantly use mass mobility and autonomous vehicles, the current funding scheme will be nearly useless.<sup>18</sup> Drivers of

electric vehicles use the roads, but aren't yet taxed accordingly.

Australia's energy suppliers face a similar dilemma. Customers that have invested in solar energy and batteries are now paying less for utility services, but large-scale public infrastructure assets need to be maintained.

“Demand management will need to be increasingly part of the conversation when we talk about infrastructure, because you can't just continue to build new capacity,” says Mr Dwyer. “We have to find new ways of dealing with demand of the system.” Measures frequently discussed include changes to toll roads, peak and off-peak pricing and congestion charging: effective measures for mitigating congestion flexibly without the need for infrastructure upgrades.

To ease crowding, some new roadways are needed, but experts we spoke to suggest that existing roads can also be better optimised to distribute traffic—and that this approach allows cities to be more flexible to uncertain future demand. Alternative transport, such as railways, trams and metro lines, can also benefit from a reboot.

“There's a balance to be struck between the development of road versus rail systems. At the moment, it is too much weighted towards motorways, and the existing rail system in Sydney is extremely crowded,” says Glen Searle, adjunct associate professor in planning at UQ. “We're reaching levels of overcrowding similar to the Tokyo subway. We have 190% overcrowding on the Parramatta-Central Sydney route.”

17. Infrastructure Australia, Infrastructure Priority List March 2018, [http://infrastructureaustralia.gov.au/policy-publications/publications/files/Australian\\_Infrastructure\\_Plan\\_March-2018.pdf](http://infrastructureaustralia.gov.au/policy-publications/publications/files/Australian_Infrastructure_Plan_March-2018.pdf)



**Australia is moving from the hundred-year-old centralised energy system to what will probably be the most distributed energy network in the world over the next couple of years, and we haven't quite wrapped our head around it.**

*Peter Colacino, Infrastructure Australia.*

### ***Evolving energy supply and demand***

As populations rise, so does energy demand. But the future demand for energy is almost as difficult to forecast as its future cost, and energy security is not certain against transformation in electricity use patterns. Recent trends and forecasts show that machines are becoming both more energy dependent and more energy efficient. And as electric vehicles increase in market share, they are noticeably disrupting the typical distribution of peak and off-peak demand through night-time recharging.

Globally, countries are working to better future-proof against energy price shocks and security issues through increasing use of alternative energy sources. For example, Japan is building up its share of renewable generation and transitioning from a centralised energy system to a hybrid one, partially in response to the shock to the energy system in the aftermath of the April 2011 tsunami.<sup>19</sup>

The composition of Australia's energy supply is unique. For example, Australia has one of the world's highest rates of residential solar rooftop uptake: nearly 15% of households have panels on their roof.<sup>20,21</sup> Australia is also a global leader and among the quickest growing markets for residential energy storage batteries.<sup>22,23</sup> These are remarkable gains in the shift towards alternatives, but Australia's infrastructure is not yet suited to new decentralised energy sources, where electrical generation and storage is performed by a number of smaller sites, including homes and businesses, rather than large power plants, resulting in gains that are not used efficiently.

"Australia is moving from the hundred-year-old centralised energy system to what will probably be the most distributed energy network in the world over the next couple of years, and we haven't quite wrapped our head around it," adds Mr Colacino.

"Customer-side generation is becoming increasingly important and in a relatively short space of time," says Geoff James, research principal at the Institute for Sustainable Futures at the University of Technology Sydney (UTS). "Already, users generate about 25% of Australia's renewable energy, and customer-side generation is expected to account for 50% of all electricity generation by 2050." Mr James adds that it won't be long before the off-peak period is in the middle of the day. "I'm sure we'll be the first country to achieve that by a very long shot. Our solar penetration is higher than anyone else's, particularly behind the meter."

And as the price of batteries declines and people increasingly adopt electric vehicles, people will have more batteries either in their car or supplementing their household energy use. Ultimately, the way Australians interact with the energy network will be different.<sup>24</sup>

### ***Continuous disruption***

Governments depend on infrastructure networks—transport, communication, energy, water supplies, etc—to deliver essential services to citizens. Unfortunately, ageing and vulnerable infrastructure, exacerbated by population growth, rapid urbanisation and climate change, is in serious need of repair or replacement. In some American cities, for example, water and sewage pipes are over a century

18. ABC News, Electric car growth and greater fuel efficiency spark calls for change to fuel excise funding, <https://www.abc.net.au/news/2018-08-28/changes-required-to-fuel-excise-funding-before-electric-car-boom/10175402>

19. World Energy Council, World Energy Trilemma Index, <https://www.worldenergy.org/wp-content/uploads/2017/11/Energy-Trilemma-Index-2017-Report.pdf>

20. Australian Energy Council, Renewable Energy in Australia, [https://www.energycouncil.com.au/media/1318/2016-06-23\\_aec-renewables-fact-sheet.pdf](https://www.energycouncil.com.au/media/1318/2016-06-23_aec-renewables-fact-sheet.pdf)

21. PowerScout, Why Is Home Solar Power So Much More Common in Australia?, <https://powerscout.com/site/home-solar-power-much-common-australia>

22. Climate Council, Fully charged: Renewables and storage powering Australia, <https://www.climatecouncil.org.au/resources/battery-storage-2018/>

old, laid deep under the city streets. And many central roads, bridges and tunnels are deteriorating. In the UK, risk of widespread flooding from climate change threatens water and power supplies to large urban areas and surrounding regions.<sup>25</sup>

Resilience in infrastructure, particularly resilience to natural disasters and weather events, is especially important in an Australian context. The building of new infrastructure is not always the best option to meet infrastructure challenges. Some of the most important gains can be made by readying existing infrastructure for future changes and needs. However, development projects cause disruption to the flow of city life, which is already taking hold in the form of 'development fatigue' among residents of Australian cities.<sup>26,27</sup>

Harry Quartermain, principal planner at Ethos Urban, a consultancy, says that the level of disruption associated with large construction projects is starting to shape the political discourse. "If you walk around Sydney's central business district you'll notice construction awnings over a vast number of buildings, thanks partially due to our recent property boom, but also due to the construction of a new Metro Rail line," he says. Other major works in the city include extensions to the main motorways and increases in building density surrounding new stations of the Sydney Metro rail project. Together, such projects create an environment of continuous development that some are starting to find exhausting. There is also an economic cost, for example through disruption to business activity through road closures and diversions.

23. Renew Economy, Australia to lead storage boom, as home batteries become 'ubiquitous', <https://reneweconomy.com.au/australia-lead-storage-boom-home-batteries-become-ubiquitous-22221/>

24. Australian Energy Market Operator, Operational and market challenges to reliability and security in the NEM, <https://www.aemc.gov.au/sites/default/files/2018-03/AEMO%20-%20received%2020%20March%202018.pdf>

25. Parliamentary Office of Science and Technology, Resilience of UK Infrastructure, <https://www.parliament.uk/documents/post/postpn362-resilience-of-UK-infrastructure.pdf>

26. The Sydney Morning Herald, Record housing approvals drive development fatigue, planning bureaucrat says, <https://www.smh.com.au/national/nsw/supply-supply-supply-record-housing-approvals-drive-development-fatigue-planning-bureaucrat-says-20171208-h01a13.html>

27. The Sydney Morning Herald, Sydneysiders in revolt over development as two-thirds declare the city is 'full', <https://www.smh.com.au/business/companies/sydneysiders-in-revolt-over-development-as-two-thirds-declare-the-city-is-full-20171008-gyw1hc.html>

### ***Eroding pipes, eroding value***

Australia has an incredible amount of ageing infrastructure that it is working to update, maintain or replace. This is notably the case in the urban water sector, where about 70% of the value is in the pipeline network and about 30% in the treatment systems. Although demand for water and sewer systems is rising with population growth, it is expensive to replace pipes and substitute them for bigger ones. Maximising existing capacity and lifetime is a major cost-saving incentive.

According to Jurg Keller, deputy director of the Advanced Water Management Centre at UQ, the challenge is daunting. In some places concrete pipes are corroding at a rate of up to 5-10mm a year, reducing the pipes' expected lifetimes of around 50 years to just one or two decades. To combat this, UQ researchers and water utility engineers are drawing on system demand and customer use data to model sewer pipeline networks and applying targeted chemical treatments to reduce the build-up of highly corrosive hydrogen sulphide. So far, this has helped, but more innovation is needed to maximise the longevity of these critical assets and ensure the infrastructure flexible to future demands.

### ***Jobs of the future: STEM skills shortfalls***

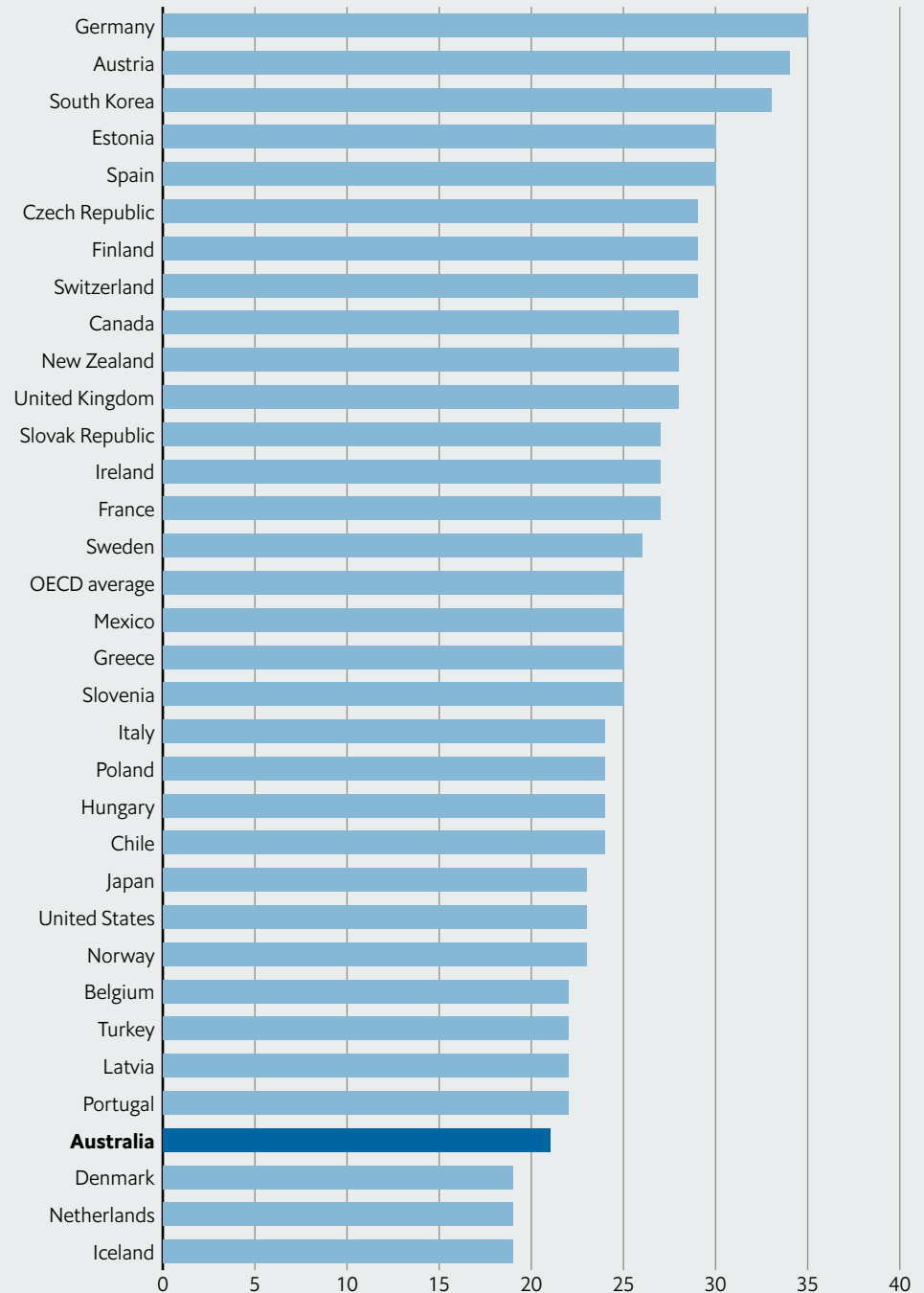
Many infrastructure-related jobs of the future will require workers to have a high level of education in STEM, especially as more innovative and technologically driven developments become the norm. Cities cannot continue to develop and meet the needs of an uncertain future without a trained, competitive workforce to build and maintain them.



**Figure 4: Australia lags behind the average of OECD countries when it comes to the percentage of tertiary graduates studying STEM subjects, 2015**

**Tertiary graduates in the natural sciences, engineering and ICTs 2015**

(as a % of all tertiary graduates)



Source: OECD Science, Technology and Industry Scoreboard 2017.

Unfortunately, it is generally agreed that, as in many countries, Australia's national investment in STEM skills is falling short. Strong levels of infrastructure construction continue to drive demand for civil engineering professionals, and though graduate completions in engineering bachelor degrees have increased year on year since 2008, the Australian Government has identified a shortage of civil and mechanical engineers, with 59% of vacancies filled in 2017-18.<sup>28</sup>

With many infrastructure projects happening at the same time, particularly on the east coast, there is concern that the industry is competing for the same, limited pool of skilled workers. More could be done to mitigate risk of a boom and bust cycle in worker demand, but longer-term, interviewees agreed that Australia simply needs more STEM graduates.<sup>29</sup>

"Australia has a problem," says Dr Catherine Ball, Founder and Executive Director at World of Drones. "We have got STEM skill shortage. It's something that has persisted for a long time and it's actually getting worse. We have got a shortage of people with the STEM skills we need to fill, and the difficulty is that the number of jobs that require STEM skills is increasing faster than the graduates are increasing from universities."

Despite the relatively low STEM-skilled workforce, the value of STEM skills is well understood among Australians. "The problem seems to be that for a large proportion of the population, they actually value it for someone else," says Peter Aubusson, professor of education at UTS. "They see STEM as critical to Australia's capacity economically and technologically, and in terms of the good life that one can live in Australia. But when it comes to individuals making decisions about the importance of STEM to themselves and their education, we see a very different picture."

Many students stop participating in STEM courses as soon as it is no longer compulsory—around year 10. Beyond this point, voluntary study in technology and engineering is far below that of continued study in physics and biology and maths.

Change to the education system is underway. "Australia's long-term vision for Australian students is absolutely focused on 21st century skills," says Verity Firth, Executive Director at the Centre for Social Justice and Inclusion at UTS, and former Minister for Education and Training. Australia has national and state-based curriculums that teachers use, and accredited teacher standards. This gives the federal and state governments an important ability to influence the direction of education at the primary and secondary level.

"The long-term vision for education from all of the key stakeholders here is that we need an education system that is agile and able to adopt 21st century skills," says Ms Firth. "This includes both STEM content knowledge as well as other soft skills—such as the capacity for critical thinking, the capacity for collaborative inquiry and working across different subjects. But how exactly we do that is one of the big debates that's going on in Australia at the moment."

28. Department of Jobs and Small Business, Skills Shortages Research | Engineering Professions, <https://docs.jobs.gov.au/system/files/doc/other/ausengineeringprofcluster.pdf>

29. Financial Review, Engineering jobs boom on \$100b infrastructure pipeline, <https://www.afr.com/business/engineering-jobs-boom-on-100b-infrastructure-pipeline-20170907-gycyuq>

### WANTED: MORE WOMEN IN STEM

Promoting and encouraging women in STEM is a continuing challenge for universities and industry around the globe. Within Australia, the STEM-qualified population is only about 16% female. And in engineering—a key discipline for infrastructure-related careers—the female distribution is only 7%.<sup>a,b</sup>

“There is still a huge gender gap in STEM in Australia—not hugely dissimilar to comparable countries, but it is significant,” says Ms Firth.

“The years we’ve taken the hit in gender diversity rankings are also the years we’ve taken a hit in the innovation rankings,” adds Dr Ball. “Correlation is not causation; however, I do feel that diversity is absolutely fundamental to having an innovative approach to how you work.”

Australia has invested in programmes that

engage girls in high school and try to ensure that they don’t drop some of the prerequisites for a STEM career. There is also investment pouring into university programmes to improve the loss of female academics in STEM.

“What has been discovered in Australian universities is the sort of patterns that we see elsewhere: a very small representation of women both at graduate, postgraduate and academic level in our engineering and IT faculties,” explains Ms Firth.

“Everyone knows that women’s ability in maths and sciences is not beyond question,” she adds. “But maintaining their participation and making sure that they’re treated equally and given the same opportunities in the workplace is where there’s a really big structural issue in Australia.”

(a) [https://www.chiefscientist.gov.au/wp-content/uploads/Australias-STEM-workforce\\_full-report.pdf](https://www.chiefscientist.gov.au/wp-content/uploads/Australias-STEM-workforce_full-report.pdf)

(b) <https://amsi.org.au/wp-content/uploads/2014/08/RobertsGenderSTEMreport2014.pdf>

(c) <http://www.abc.net.au/news/2018-08-13/fact-check-global-gender-gap/10051632>

## Chapter 3

# OPPORTUNITIES IN GROWTH: INNOVATIONS IN INFRASTRUCTURE

City officials are rethinking urban design and resilience from almost every angle. “Future proofing”, or the flexible building and designing of infrastructure, is now a common consideration in the early stages of planning.

This chapter will highlight cases of innovative, flexible development solutions being applied across the globe. Smart materials, the gradual arrival of driverless car technology and advanced robotics are some of the driving forces behind new approaches. Through these, buildings and networks are being constructed to be more responsive to demand shifts and future needs.

The examples described in this chapter are often site-specific, operating on the bleeding edge of new capabilities and concepts afforded by new technologies and data. But across the board, it is clear that flexible building ideas are beginning to alter the way that planners approach, design and inform future projects.

### ***Data-driven cities***

Modern cities produce vast amounts of data that can be used to optimise both their day-to-day operation and longer-term design. Technological developments such as the Internet of Things (IoT) rapidly expand the volume, velocity and variety of transport and mobility data.

Most cities have a few data-driven initiatives to showcase: in London and across the UK, a smart traffic management system coordinates traffic flow by sensing, through wireless magnetometer or inductive-loop traffic detectors, congestion at intersections across the city. The Virginia Department of Transportation in the US implemented dynamic toll pricing on a busy interstate, made possible by real-time data collection of road use. And in Chicago, streetlight systems self-report malfunctions to better keep high-crime areas lit at night.<sup>30</sup>

Numerous data applications can be found in Australia’s smarter cities—the most advanced of which are the City of Adelaide, City of Ipswich and City of Canterbury Bankstown—where distributed sensors collect relevant data on city activity to better inform decision-makers about congestion, health, heat, transport, safety, activation, events and community cohesion.

But in other cities, connectivity is being built in from the ground up, connecting entire neighbourhoods. In Quayside, a neighbourhood in Toronto, dozens of acres of formerly industrial coastal land is being rebuilt, by Google’s Sidewalk Labs venture, as a highly sensor-enabled smart-city that, through continuous generation and analysis of data, is nearly ‘self-run’.<sup>31</sup>

<sup>30</sup> Government Technology, Updating Infrastructure is Essential to Building Smart Cities, <http://www.govtech.com/fs/Updating-Infrastructure-is-Essential-to-Building-Smart-Cities.html>

<sup>31</sup> Politico, Google Is Building a City of the Future in Toronto. Would Anyone Want to Live There?, <https://www.politico.com/magazine/story/2018/06/29/google-city-technology-toronto-canada-218841>

Data can aid city operation, but it can also help inform the very design of cities and city services to be more efficient. For instance, the Seoul government designed the routes of its new night bus services based on an analysis of night-time mobile phone location data. The city worked with private telecoms companies to analyse calls made between midnight and 5am, and matched this data, anonymously and in aggregate, with billing addresses to determine which routes would experience greatest demand for overnight services.<sup>32</sup> Meanwhile the city of New Orleans has optimised the locations of its ambulances on standby, based on patterns of emergency calls.<sup>33</sup>

Kerryn Wilmot, research principal at the Architect Institute for Sustainable Futures at UTS is currently using ticketing data to inform transport policy and procurement decisions. “When we put scenarios of the new transport infrastructure in place, we make predictions based on travel time and origin and destination about how, for example, people’s travel patterns would change if a new train line is put in place,” she says.

Access to data is also crucial for the confident future-proofing of cities. Data analytics in scenario planning is helping calculate ways structures can be used more productively and in a relevant way as citizens’ demands evolve. Effective and responsible use of the growing wealth of data requires successful navigation of a number of difficulties. Standardisation of data remains an issue, and more has to be done to address concerns over personal data privacy and security—including settling complex questions of ownership (see box).

Those interviewed for this report agreed that governments and stakeholders need access to open and shared data to inform macro infrastructure decisions at the highest level, right through to running smarter infrastructure day to day.

Mr Davies adds that with the convergence of some sectors, like transport and energy, joined-up planning, based on shared data, is essential to building flexible cities. “We need data for academics and others to model and think about these issues. They need data for scenario-planning and for presenting options to government to make sure we’re agile to future transformation.”

### DATA PRIVACY SOLUTIONS ON THE HORIZON

More data brings more complexity. And to critics, mass data gathering is linked with tracking and surveillance. Australia is still learning how best to harness the powers of smart sensors, in particular how to govern and protect citizen’s personal data. These are roadblocks shared around the world. But as data-driven solutions continue to advance, Australia is under pressure to find its own resolution.

“We’ve got some really interesting problems to be solved, and I think we are still in the embryonic stages,” says Tim McMinn, Senior Manager at PwC Australia. “It’s a really important challenge and something that Australia is at the point of needing to get its head around today,” says Mr Colacino. One possibility is passing legislation similar to the General Data Protection Regulation (GDPR), which protects the data and privacy of

<sup>32</sup> Apolitical, Seoul uses citizens’ late night calls to plan new night bus routes, [https://apolitical.co/solution\\_article/seoul-uses-citizens-late-night-calls-plan-new-night-bus-routes/](https://apolitical.co/solution_article/seoul-uses-citizens-late-night-calls-plan-new-night-bus-routes/)

<sup>33</sup> New Orleans Office of Performance and Accountability, NOLAytics, <https://datadriven.nola.gov/nolalytics/>

individuals within the EU. “We need to think about, for instance, connected car technology and who owns that data, and how can it be used to better plan.”

Kylee Anastasi, partner of Infrastructure and Urban Renewal at PwC Australia, adds that stakeholders are grappling with how to maintain privacy, how to set the platforms, and what regulations is needed. “Work in this area is progressing, but I think Australia still has some structural considerations we need to work through in order to really harness that and accelerate our use of data,” she says.

City governments are beginning to take a more considered and responsible approach to the collection and use of personal data.

Barcelona, for instance, has launched a new procurement process designed to incentivise responsible use of data with respect to privacy, introducing clauses into contracts around data sovereignty and public ownership of data.<sup>34</sup> Amsterdam has set about compiling a registry of all publicly installed sensors. New York City’s government has developed Internet of Things Guidelines, which establish privacy standards for the deployment of IoT devices in public spaces. In Australia, Transport for New South Wales has collaborated with Data61, a data innovation group, to release open data about citizens’ use of Sydney’s public transport network in a robustly anonymised fashion to minimise privacy risks.<sup>35</sup>

### ***Intelligent upgrades to traditional infrastructure***

Building flexibly means thinking and building differently. New technological capabilities make it easier to embrace new designs and adapt traditional assets for tomorrow’s needs.

Classic building features, such as the cement used in roads and footpaths, are already undergoing rapid technical transformation. Advances in material sciences, many from university labs, such as “programmable cement”, “self-healing concrete” or even solar-harvesting roadways, are increasingly being trialled, with the aims of cost saving and building resilience to environmental change.

Pipelines are a prime asset in need of innovation. Replacing them is expensive, and improving efficiency can involve complex processes. Indeed, many have not been touched since they were first laid in city foundations decades—even more than a century—ago.<sup>36</sup>

Cities are still learning how to future-proof these critical assets. Mr Keller explains that, in Australia, early-stage development is underway to increase efficiency by integrating disparate water systems. “Traditionally, we have developed and operated separate water supply, sewer and stormwater/drainage systems, when in actual fact they’re all interconnected and need to be utilised in an integrated approach.”

But progress is being made. For example, Aquarevo, a newly developing community in south-east Melbourne is possibly the first of its kind to build an integrated water system on a wide scale. The local water utility, South East Water, will own and operate the gutters, rainwater tanks and hot water systems of every house in the 450-lot development, as well as a centralised water recycling system for

<sup>34</sup> WIRED UK, Barcelona is leading the fightback against smart city surveillance, <https://www.wired.co.uk/article/barcelona-decidim-ada-colau-francescabra-decode>

<sup>35</sup> Nesta/Decode, Reclaiming the Smart City: Personal data, trust and the new commons, <https://www.nesta.org.uk/report/reclaiming-smart-city-personal-data-trust-and-new-commons/>

<sup>36</sup> The New York Times, \$300 Billion War Beneath the Street: Fighting to Replace America’s Water Pipes, <https://www.nytimes.com/2017/11/10/climate/water-pipes-plastic-lead.html>

outdoor usage and toilet-flushing, in addition to the traditional water supply and wastewater services. By using smart, integrated water management (such as redirecting recycled water for gardens and toilets), the community anticipates reducing potable water demand by 70% while also minimising sewer and stormwater discharges.<sup>37,38</sup>

“That’s the sort of innovation that you need to look for—if you need to service twice the population without having to double all of the infrastructure, that’s the smart and very cost-effective way to do it,” says Mr Keller.

### CASE STUDY FROM SALINI IMPREGILO

#### *Lake Mead Intake Hydraulic Tunnel, Las Vegas, US—2008-16*

The Lake Mead Intake Hydraulic Tunnel was conceived to mitigate the effects of a long drought in the Colorado River basin by guaranteeing the supply of water to nearly 2m residents in the Las Vegas area.

Dubbed the “third straw”, it has come to complement two other pipes that sometimes run the risk of being exposed to the air whenever the lake’s water level suffers a severe drop in times of drought. Set on the lake floor, the third pipe never risks running dry.

Completed in 2016, the project comprises a shaft on the shore of the lake that goes down 200 metres to the mouth of the tunnel. Water drawn from the intake’s opening in the middle of the lake flows through a series of tunnels and shafts for a total of 4,600 metres before being pumped to a treatment plant. It then heads to the city.

The project was a unique experiment in hydraulic engineering. The drilling of the tunnel by Salini Impregilo under Lake Mead, one of the largest artificial lakes in the US, set a record in the world of

engineering. The theoretical water pressure above the heads of the workers steering the tunnel-boring machine (TBM) through the rock was up to 15 bars rather than the usual 1-3 bars. No other mining job in the world had ever been done under such pressure. The TBM had the potential exposure to hydrostatic pressure of approximately 17.4 bars if the lake had been at its maximum capacity. And it is the deepest sub-aqueous tunnel in the world constructed with a pressurised-face TBM.

To approach such a complex project, an innovative shared risk approach was implemented to ensure the full commitment of all parties, to reduce the contingencies in the contractor’s costs and owner’s budget, as well as to reduce the risk of uncertainties. Entering into a shared risk model ensured that both parties were more committed to the final goal. This approach ensured an informed, timely and effective joint decision-making process for the benefit of the project, which would later win a number of industry awards.

<sup>37</sup> CRC for Water Sensitive Cities, Aquarevo case study, <https://watersensitivecities.org.au/solutions/case-studies/aquarevo/>

<sup>38</sup> South East Water, Aquarevo: A new way of living, <http://southeastwater.com.au/CurrentProjects/Projects/Pages/Aquarevo.aspx>

### BIM READY

Building information modelling (BIM) has become increasingly popular in the global construction industry, transforming the way that buildings and infrastructure are designed, constructed, and operated.

BIM is the digital representation of the physical and functional characteristics of a building or place, allowing many disparate stakeholders to contribute data to a single, shared project model that can inform decision-making for all. The approach is particularly valuable for diverse and large-scale physical infrastructures.

Infrastructure projects that have used BIM have reported substantial benefits including cost and time savings, and reduced risk: surveys report up to 20% reductions in build costs and further savings in costs over the lifetime of the asset of up to a third. Potential savings

through greater adoption are estimated to be much higher.<sup>39</sup> However, as BIM brings change in the way projects are procured, designed, delivered and operated, its adoption requires a significant programme of change.

The Australian federal government, as well as some state governments, have eagerly promoted the adoption of BIM, suggesting BIM could be mandated for government or government-funded works.

In Queensland, for instance, a new policy for BIM, currently in draft form, proposes that projects delivered by the state government would require BIM where feasible. A 2018 survey of Queensland architects found that 78% of metropolitan practices and 71% of regional practices currently use BIM.<sup>40</sup>

### ***Metro of the future***

The highly anticipated Sydney Metro, Australia's biggest public transport project, will feature a driverless mass-transit system that is anticipated to nearly double the city's existing transit capacity. Operations of the 36-km Northwest line are expected to start in 2019.

"By building the Sydney Metro, I think we are copying the best of urban rail policy around the world," says Mr Searle. "It is the right time to introduce it."

Existing transport systems are getting an upgrade, too. The ageing train control systems along the West Australia Transperth rail network and Melbourne's Metro Tunnel are gradually being upgraded with digital Communications-Based Train Control (CBTC) systems, a global standard for high-capacity metro systems that allows trains to be operated automatically and without signalling. Trains can then run closer together on the same amount of track. For Perth, it is suggested that these upgrades could increase train service frequency by 150%.<sup>41</sup>

<sup>39</sup> PwC, BIM Benefits Methodology and Report, <https://www.cdbb.cam.ac.uk/BIMLevels/BBM>

<sup>40</sup> Association of Consulting Architects Australia, BIM Ready: BIM Capability of Queensland architects in 2018, <https://aca.org.au/article/new-bim-ready-report-released>

<sup>41</sup> Intermedium, Next gen train control system on WA's radar, <https://www.intermedium.com.au/article/next-gen-train-control-system-wa%E2%80%99s-radar>



### CASE STUDY FROM SALINI IMPREGILO

#### ***Cityringen Metro, Copenhagen, Denmark—2011-***

Under the CPH Climate Plan 2025, Copenhagen wants to become carbon neutral in ten years' time. The metro system is one of the components of this plan to reduce CO<sub>2</sub> emissions from about 2.5m tonnes to less than 1.2m tonnes.

By 2025 Copenhagen wants 75% of trips made by residents to be done by foot, bike or public transport. This is one of a series of targets listed on the website of C40, an international network of cities dedicated to fighting climate change.

The Cityringen project in Copenhagen is one of the main projects that will help the city to become an example of a "Flexible City", able to reach such an ambitious goal.

The Cityringen is a driverless metro that will form a new circular line in the centre of the city. It will contribute to make Copenhagen the greenest city in the world by helping place 85% of its residents within 600 metres of a metro or train station when it opens in 2019.

Cityringen consists of two parallel tunnels some 15.5 km long and 17 underground stations, situated an average of 30 metres below street level. The metro will connect with an existing metro line as well as bus and train stations, giving people even fewer reasons to get in their cars. The tunnels were excavated using tunnel-boring

machines. Only the service tunnel in Norrebroparken was excavated using traditional methods.

The fully automated line is driverless and, once fully operational, will provide a 24-hour transport system that guarantees the mobility of 240,000 passengers a day (or 130m a year).

Due to its position in the centre of the city and its high level of complexity, the project faced some major challenges in its realisation for the contractor, the Copenhagen Metro Team (CMT) consortium, of which Salini Impregilo is a part. In fact, the works are carried out in a densely populated area, close to historical buildings such as the Magasin Du Nord in Kongens Nytorv and Marmorkirken (the Marble Church), a famous church in Copenhagen. Working underground presented some major issues that had to be faced, such as contaminated soils and the risk of flooding.

All of those challenges were addressed by improving co-operation on-site among contractors, trade unions and the workers themselves. With more than 24 nationalities at the worksite from countries such as Denmark, England, Ireland, Romania, Italy, Bulgaria and Portugal, it was crucial to create a cohesive culture, especially in health and safety. The result was a lost time injury frequency rate that dropped to new reference values in Denmark, with 0-value achieved in December 2017. The following year, more than 14 sites went without any lost time injuries at all.

### ***Construction and repair, revisited***

The construction industry is traditionally manual and labour intensive. But automation and innovation are rapidly transforming traditional processes, making for more cost-effective investments and more resilient infrastructure.

Globally, the infrastructural health monitoring market is forecast to grow from US\$1.48bn in 2018 to US\$3.38bn by 2023.<sup>42</sup> This is linked to the surge in infrastructure development, rapidly ageing existing infrastructure such as bridges, dams and tunnels, and the high costs associated with catastrophic failure. New monitors improve traditional (visual) inspection by providing structural assessments to stakeholders for repair and maintenance efforts, and a feedback loop to improve future development.<sup>43</sup>

Within construction monitoring, advances are being explored to help reduce the cost, extent and time of builds. Mr Washington explains that buildings today are designed with factors of safety that are necessarily large as a result of design and construction practices, requiring that developers end up spending significant time, money and energy to achieve these high factors of safety. “If we could use sensors, for example, to monitor the health of infrastructure on a real-time basis, we could detect infrastructure that has fallen below acceptable factors of safety, to then manage through maintenance, rehabilitation, or replacement. This approach could drastically reduce infrastructure build, rehabilitation, and maintenance costs.”

This application is starting to become a reality in building sites. Behzad Fatahi, associate professor in Civil-Geotechnical Engineering at UTS explains that monitoring with sensors is increasingly being used in the design and construction of roads, tunnels and railway lines.

In many new projects, Mr Fatahi says, including the Gerringong upgrade project in the south of Sydney, a big part of the Princes Highway Upgrade, monitoring sensors are embedded during construction to measure the progression of soil settlement and movement of the foundation. Traditionally, builders periodically test the soil for settlement manually, a process that halts construction, and takes time and considerable expense. “Now we see that construction can be done much faster and we can optimise the design,” Mr Fatahi says. “Of course, we want to be safe, but we don’t want to be over-safe or spend too much money, because that comes with a cost.”

### ***Eliminating danger using new technologies***

New technology—often previously the stuff of science fiction—is increasing safety in infrastructure management. For example, in the Sydney sewage pipelines, a robot is now doing a job no human can safely do: inspecting the ageing pipes for signs of corrosion and sending back signals and pictures of problem areas. Above ground, workers armed with data can dig to these locations and address the issues, extending the lifetime of pipes in a way not previously possible.

And in landfills—dangerous zones for people due to toxic gasses and unstable footings—robots and drones are increasingly employed. Already in the US, drone technology is allowing landfill managers

<sup>42</sup> Structural Health Monitoring Market by Technology, Offering, Vertical, Application, and Geography—Global Forecast to 2023, [https://www.researchandmarkets.com/research/czh4xq/3\\_3\\_bn?w=5](https://www.researchandmarkets.com/research/czh4xq/3_3_bn?w=5)

<sup>43</sup> IIT Kanpur, Structural Health Monitoring presentation, [http://www.iitk.ac.in/ce/test/MoHUPA%20Presentation\\_Dr.K%20Roy%20\\_%20Dr.S.Mukhopadhyay.pdf](http://www.iitk.ac.in/ce/test/MoHUPA%20Presentation_Dr.K%20Roy%20_%20Dr.S.Mukhopadhyay.pdf)

increase the lifespan and capacity of the sites they oversee. According to Texas-based Firmatek, some managers receive “a monthly scan when closing a cell to guarantee maximum precision, ensuring that available space is used as efficiently as possible ... And drones allow for cost-effective data acquisition, whether it’s 3D modelling or mapping of groundwater systems.”<sup>44</sup>

In Australia robots are being uniquely used to test conditions in landfills for redevelopment for railway lines and roads. This is currently an issue for a section of the planned railway line to the Moorebank Intermodal Terminal in Southwest Sydney. The land targeted for railroad is built on top of an old landfill, and sampling of the foundation can be dangerous. Instead, specialised robots and drones affixed with sensors are being sent in to run analysis on the composition of the land so that engineers can design accordingly.

### ***Seizing the energy evolution***

Energy security is a priority for most cities across the globe. Risks of energy shocks and disruption to gas and oil supply chains, either by climate change or international conflict, have fuelled interest in more sustainable, alternative energies. At the same time, significant focus is being put towards the transformation of old fossil-fuel energy systems to make them compatible with new, sustainable sources.

Australia is committed to the energy evolution. Global investment in renewables totalled US\$298bn in 2017, according to the International Energy Agency—a 7% drop from 2016 levels.<sup>45</sup> But Australia’s investments in clean energy technologies increased by 150% year on year, to reach a record high of AUD\$9bn, most of which went towards utility-scale wind and solar projects.<sup>46</sup>

The focus on renewables has also given rise to energy storage technologies, which ensure reliable energy supply at peak times, when the wind slows or when the sun is not shining.

Pumped hydro energy storage is one method to help bridge the gap between solar and traditional utility. This is a hydroelectric energy storage system that makes use of the gravitational pull of water. It involves two reservoirs, one at a higher elevation to the other. When low-cost energy is being generated, such as through wind or solar generation, water is pumped to the top reservoir. When energy demand or costs are highest, water is released down to the lower reservoir through turbines, thereby generating energy.<sup>47</sup>

Mr James says that, in Queensland, a substantial pumped hydro capacity is being built in a disused mine that uses the vertical height difference. “That’s getting a huge amount of interest, and people are looking around for sites where that model can be replicated because there’s pretty much no environmental concern. It’s already a site that needs rehabilitation, and this is a way to use the hole in the ground.”

Mr McMinn adds that the time is ripe for further development of technology around managing distributed energy iterations of the grid. “It’s early days but there are little pieces of innovation going

44 Firmatek, 3 Tech Solutions for Modern Landfills, <http://www.firmatek.com/2018/08/30/3-tech-solutions-for-modern-landfills/>

45 International Energy Agency, Global energy investment in 2017 fails to keep up with energy security and sustainability goals, <https://www.iea.org/newsroom/news/2018/july/global-energy-investment-in-2017-.html>

46 Bloomberg NEF, Runaway 53GW Solar Boom in China Pushed Global Clean Energy Investment Ahead in 2017, <https://about.bnef.com/blog/runaway-53gw-solar-boom-in-china-pushed-global-clean-energy-investment-ahead-in-2017/>

47 Corrs Chambers Westgarth, Pumped hydro, <http://www.corrs.com.au/thinking/insights/pumped-hydro-the-next-big-thing-in-australias-electricity-landscape/>

on.” For example, an Australian company called Power Ledger, which has since expanded to the US, has established a blockchain-enabled peer-to-peer renewable energy trading system for households and businesses.<sup>48</sup>

### GOING OFF GRID

Microgrids are an increasingly popular way to locally distribute electricity and improve reliability during outages. As the consequences of climate change become more dramatic, interest in microgrids is rising internationally.

Panasonic, a Japanese technology firm, has taken an interest in this area and is working to roll out smart grid infrastructure in the US after a successful trial in Japan, in which the company connected 1,000 homes in Fujisawa Sustainable Smart Town, west of Tokyo. Here, all homes and offices are connected to a solar-powered smart grid, giving the neighbourhood the ability to run off-grid for up to three days. In addition, Panasonic reported that the

community released 70% less carbon and had a 30% return of energy back to the grid.<sup>49</sup>

Microgrids are particularly suited to Australia, where the vast distances covered by energy distribution networks present a challenge. Microgrids keep power local and lower costs by cutting much of the associated costs of distribution. In Western Australia, Horizon Power uses microgrids to provide power to remote towns across the region of Pilbara. Onslow, a small town north of Perth, hosts Australia’s largest microgrid and aims to source more than half of its power from renewable energy.<sup>50</sup>

48 TechCrunch, Power Ledger deploys first blockchain-based P2P energy trading system in Chicago, <https://techcrunch.com/2018/05/03/power-ledger-deploys-first-blockchain-based-p2p-energy-trading-system-in-chicago/>

49 Power Technology, Smart cities: redefining urban energy, <https://www.power-technology.com/features/smart-cities-redefining-urban-energy/>

50 Horizon Power, Onslow fact sheet, <https://horizonpower.com.au/media/2763/onslow-fact-sheet.pdf>

## Chapter 4

# AUSTRALIA'S COLLABORATIVE APPROACH TO DEVELOPMENT

Technological innovations and flexible build initiatives are not only changing the design of physical assets, they are transforming the scope of projects and the strategies that governments and stakeholders use to manage and incentivise them.

In this chapter we explore changes to the way that stakeholders think about planning, and how evolving future challenges are being considered in the early stages of procurement and design.

### ***Advanced procurement***

Australian governments have traditionally allocated each of the phases of infrastructure development—design, construction and maintenance—to different companies. However, firms often disagree with one another, resulting in problems in terms of continuity and opportunity for disruption. Today, this is less often the case, as governments are improving procurement in a few ways.

Mr Fatahi says it is now more common to see the allocation of all phases to one large firm or joint venture. Under this model, a single entity looks after the design, construction and maintenance of the project for extended periods.

“Because they are the people who are going to look after these projects, they have more motivation to utilise technology,” explains Mr Fatahi. “They know that they will have to deliver it, therefore they already have an incentive to make sure that they do things more efficiently.” With this in mind, stakeholders make more and better use of technology to maximise long-term value, and to ensure the asset is flexible enough to adapt to future changes in usage.

Professor Ghassan Beydoun, deputy head of school systems at UTS also says that the procurement of large projects has improved greatly in Australia in recent years. “There’s a knowledge transfer from the UK and the US that’s been happening over the past ten years. And since moving towards their procuring systems, which involves private and public partnerships, they’ve become a lot easier to manage and a lot easier for the government’s agency team to get their heads around what needs to happen.”

In addition, the government approach to infrastructure investment is responsive to advice from independent bodies. Infrastructure Australia, the Australian government’s independent infrastructure advisor, and equivalent regional bodies provide advice on appropriate projects and policy setting for infrastructure. Long-term function is one such consideration.

“The transparency effectively puts the onus on governments to explain what they are building and why,” explains Mr Dwyer. “This approach is particularly useful to the extent that it forces government to explain deviations from independent advice.”

Governments at both state and federal levels have in recent years created a plethora of independent infrastructure assessment bodies charged with independently assessing infrastructure projects for cost benefits and for creating infrastructure priority lists. For example, in Queensland, Building Queensland, an independent statutory body is charged with leading the preparation of business cases where government investment exceeds \$100 million, as well as publishing a pipeline of infrastructure priorities for the state. At the federal level Infrastructure Australia has a similar mandate.

The creation of such bodies has not removed the politics from infrastructure planning and prioritising, but it has increased the transparency of the process and improved the rigor of project assessment. The increasing maturity of state infrastructure plans and priority lists, as well as discussion of the drivers of infrastructure demand, should improve the delivery of required infrastructure. The danger however, is that an increasingly complex planning system may lessen the ability to make the quick decisions needed to deal with changing cities.

Mr Dwyer adds that his organisation and independent advisory bodies are turning to emerging technologies to help inform a more sophisticated approach to problem identification and project selection. For example, Infrastructure Partnerships Australia's Uber Travel Time metric—a partnership with the car-sharing company Uber—collects data from vehicles for a precise, instantaneous look at driving speed and congestion levels in Australian cities.

“We publish the Infrastructure Partnerships Australia and Uber Travel Time Metric every year, and that helps to inform governments of emerging bottlenecks, emerging challenges, capacity constraint, et cetera,” says Mr Dwyer. “That’s just one discrete example of new emerging technologies being used to inform a more sophisticated approach to problem identification and project selection.”

In a wider sense the inclusion of sustainability metrics makes it possible to align procurement decisions with environmental and social priorities—without losing sight of the business imperative.

### ***Attractive financing models***

When it comes to attracting infrastructure financing, Australia has a number of advantages. It boasts a strong investment landscape and financial sector. The federal, state and local governments are also open to the adoption of global best practice and have implemented recognised standards of regulation. Australia also has a mature unsolicited proposals system, enabling the market to bring proposals to government for investment. The upshot is an attractive, open market to foreign players, inviting competition and encouraging innovation.

The federal government, under the former prime minister, Malcolm Turnbull, championed innovative approaches to infrastructure financing. While the project has yielded little in the way of tangible results, it has opened the door to new ways of funding infrastructure spending. Accordingly, the newly formed Infrastructure and Project Financing Agency (IPFA) has been set up to advise the federal government on innovative approaches to the funding and financing of significant infrastructure.

Mr Washington adds, "Australia is very creative at looking into ways to finance infrastructure and sell infrastructure when it makes sense to turn a public asset into a privately owned venture." His experience leads him to conclude that Australia explores public and private partnerships in great length and has become very creative in generation of financing for infrastructure, including through green finance.

Examples abound of Australia's competitive market at work, and of newly forged collaborations among once disparate stakeholders, such as industry, academia and government. Partnerships with international companies are also strong. "If you were to list the countries that have the most sophisticated markets, dependable pipelines, strongest private participation and sensible regulatory models," says Mr Dwyer, "the list typically starts with Canada, the UK and Australia. In some areas, Australia's at the top of that pile. And it's typically not Australia that is *following* best practice. It's typically Australia that is leading best practice or amongst that leading group."

Mr Colacino adds that there is record infrastructure investment in New South Wales and Victoria. "We've just come off a resource boom in Western Australia and a mini boom in the Northern Territory. So there have been quite remarkable levels of investment there. It's a very interesting period for infrastructure in Australia."

The results are evident: In total, there are over 230 ongoing projects across Australia and New Zealand, as highlighted by [infrastructurepipeline.org](http://infrastructurepipeline.org).<sup>51</sup> "There is about AU\$170bn worth of infrastructure activity on the East Coast alone," says Mr James. "That's a huge amount of capital investment in infrastructure, and it will last for the next couple of decades."

Many are smaller budget, incremental projects, such as adding a lane to a motorway or adding a spur to a rail line. But there are a growing number of new megaprojects that are already shaping Australia's cities, make them more resilient to future changes, and giving a long-term boost to their economies.

### ***University collaborations***

Universities are often at the forefront of technological research and have the tools to better analyse the impacts that technological and climate change can have on future infrastructure. So it is no surprise, says Mr Fatahi, that the number of construction projects that involve some degree of collaboration with higher education and academia is increasing.

In the state of Queensland, for example, the main transport agency has developed a relationship with three universities, which Mr Washington says help advise them on future scenarios so that they can start to think about the infrastructure needs of tomorrow.

However, Mr Fatahi believes partnerships between infrastructure firms and universities and research institutes should be stronger. "I consider Australia's partnerships to be behind the other modern nations such as the United States," he says, adding that Australian companies should be more inclined to approach universities and research institutes to ask about their technology.

<sup>51</sup> <http://infrastructurepipeline.org/>

“Yes, university academics can go to an industry and talk to them, but usually the final user would be the industry, so they should be more motivated to approach universities. They need to realise that there are a lot of good things done at universities that they can utilise, particularly technology-wise and in developing new materials and software ... I believe these partnerships are improving—and they must.”

### **Government collaboration**

Australia has short election cycles (parliamentarians are elected for three years) and three levels of government: federal, state and local. As with other nations with similar arrangements, this can challenge long-term approaches to infrastructure projects. The problems are exacerbated by Australia’s “vertical fiscal imbalance” which means that much of the revenue-raising capacity is held by the federal government and so is well removed from the planning and delivery of infrastructure at state and local government levels.<sup>52</sup>

“When it comes to cities, any departure in public policy between those three levels of government can have consequences to the way that infrastructure is both planned and delivered,” says Steve Abson, CEO of Infrastructure Association of Queensland.

“The planners and designers deliver the agenda, but the agenda is either set by the government, the politicians, or by the private sector,” adds Mr Quartermain.

Recent transformations within government are helping the different levels to work more collaboratively and intelligently to meet infrastructure challenges. First, rather than being prescriptive, the federal government has taken to setting targets and raising the benchmarks for innovation.

For example, the concept of the 30-minute city, a benchmark prominent within the Australian state and territorial governments, advocates that accessibility of cities should be measured by a citizens’ ability to access places or services they use on a daily basis (such as school, food, healthcare, work and entertainment) within 30 minutes.<sup>53</sup> Within Melbourne, a 20-minute neighbourhood benchmark is used.

These kinds of parameters also promote creative thoughts about flexible spaces being built today. For example, an office building that is designed with the potential to transform into a hospital or a school, based on predicted needs of future populations.

There has also been an increase in governance models that partner different levels of government. This includes City Deals, a collaboration model borrowed from the UK,<sup>54</sup> in which the federal government works with the state and local governments to drive major infrastructure programs in local areas. “City Deals is an attempt to get at a longer-range bipartisan agreement across all three levels of government to both plan and deliver infrastructure,” says Mr Abson. “And that is generally a welcome initiative that will provide at a certain level of coordination around a common narrative and a common vision for cities.”

<sup>52</sup> The Conversation, Renewing federalism: what are the solutions to Vertical Fiscal Imbalance?, <https://theconversation.com/renewing-federalism-what-are-the-solutions-to-vertical-fiscal-imbalance-31422>

<sup>53</sup> Department of the Prime Minister and Cabinet, Smart Cities Plan (2016), <https://cities.dpmc.gov.au/smart-cities-plan>

<sup>54</sup> UK Government, City Deals, <https://www.gov.uk/government/collections/city-deals>



Australian governments are now involved with many City Deals. One example is a 2017 deal between the Northern Territory Government and the city of Darwin. Under this deal, a AUD\$100m (US\$72m) ten-year plan was agreed that aims to drive local investment, create jobs, improve quality of life for residents and attract migration from other state capitals. This will yield the creation of parks and modern facilities for residents and visitors. The deal also address high temperatures through increased tree canopy and creative cooling techniques, as well as seeking to upgrade transport provision.

Australia's patchwork of overlapping jurisdictions and responsibilities in the infrastructure sphere is perhaps no more starkly illustrated than in South East Queensland (SEQ). This high-growth area has seen disputes between all three levels of government over funding, prioritisation and responsibility for infrastructure.<sup>55</sup> Increasingly, people in SEQ live in one area, their children attend school in another and they work in a third. As the region's conurbations increasingly join up, infrastructure planning that stops at the border of council jurisdictions presents a threat to sustainable growth.

A City Deal for SEQ seeks to set out an agreed plan for growth and a funding framework going forward. While getting state, federal and ten local governments to agree on 15-year rolling planning for infrastructure is a daunting task, the benefits of expanding the planning horizon beyond council borders and the three to four year terms of these governments are great.

Mr Abson adds that best practices in long-term planning are still emerging and that the model for City Deals has already drastically matured in the way that stakeholders collaborate and support growth.

"The new approach seems to be supporting good planning," adds Mr Davis. "It's early days, but it's been effective so far."

<sup>55</sup> Brisbane Times, Government map shows M1 work should have 80:20 funding, <https://www.brisbanetimes.com.au/national/queensland/government-map-shows-m1-work-should-have-8020-funding-20160714-gq5hcx.html>

## CONCLUSION

Infrastructure Australia warns that governments must start planning for another 12m people within the next 30 years—a more significant growth rate than most other nations. The opportunity this presents for socioeconomic development and innovation is significant. And in this fast-moving, interconnected global economy, every city must work harder to compete, attract and retain talent and business. Should government fail to address rapid growth in urban areas, the liveability of cities will suffer.<sup>56</sup>

The challenges that come with rapid urban growth are not easily addressed. Without strong partnerships and investment in infrastructure, as well as a willingness to take calculated risks on uncertain future scenarios, cities will struggle to provide for their citizens.

Australia's cities are, however, not shying away from these challenges. Overall, the country has shown an enormous willingness to innovate, collaborate, and learn from global leaders.

Advancement in the way cities are being designed and managed make it easier for stakeholders to achieve more in the confined space of existing city borders. New tools, from data to drones, are extending the life-span of buildings and networks. By adopting these solutions, stakeholders are more prepared than ever to future-proof cities.

The link between investment in infrastructure, the adoption of technology and improved quality of life is playing out across Australia. But more can be done. Our research has indicated that the following measures can help make infrastructure in Australia more effective, cost-efficient, and flexible to uncertain futures, greatly improving quality of life for citizens in the long term:

- **More innovative efficiency measures and maintenance of existing infrastructure.** Decades of development have created a strong foundation for future infrastructure. Although it is tempting to build new, state-of-the-art networks, many existing and ageing infrastructure works have the potential to become more efficient or be repurposed for future needs. Governments and industry are now consulting with universities and looking abroad for innovative solutions that can potentially save time and money, and make existing infrastructure more resilient to change.
- **Increased data sharing for and by governments.** Open and accessible data helps stakeholders make smarter decisions that improve the quality of life of citizens. Governments and industry need to work closely with citizens to agree on data-sharing and data-ownership solutions that safeguard privacy robustly while enabling stakeholders to deliver smarter, more efficient infrastructure solutions. Creating standards for data sharing and mandating its use in government projects, such as BIM, is an example of how government can drive more efficient infrastructure development.
- **Greater collaboration between industry, government and universities.** Universities and research institutes are furthering advances in technology, materials, software and robotics that industry can benefit from; infrastructure firms can do more strengthen these links. Partnership and programmes that encourage cooperation and R&D can be further expanded and promoted.

<sup>56</sup> The Australian, Plan now or quality of city life will decline, says Infrastructure Australia, <https://www.theaustralian.com.au/national-affairs/plan-now-or-quality-of-city-life-will-decline-says-infrastructure-australia/news-story/cd780088976dbd5b087535efdf67cfb9>

New models of collaboration between industry and government, including at the earlier problem identification and solution design phases, not just in execution, ought to be explored.

- **Stronger investment in STEM skills.** Australia is undertaking a record period of infrastructure investment, but to meet demand the country requires skilled, creative minds. The country is struggling to fill the growing number of STEM-qualified jobs across the country. To combat this labour shortage, government, industry and universities need to take new and creative approaches to retraining an existing workforce. They must also bolster funding and support for women in STEM education, and encourage more citizens and businesses to consider funding more training placements of university students.

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