

Research Review

Rethinking Systems



Rethinking Systems



At Arup we conduct independent research to test and experiment with new approaches that respond to issues our clients and communities are facing.

Covid-19 brought to the fore the importance of systems working together to support more resilient communities. It also showed us just how interconnected nature and the built environment are. It forced a moment of deep consideration of the flow-on effects of our actions and our significant impact as a global firm.

In this issue of Arup's Research Review "Rethinking Systems" we consider approaches to create better outcomes for people, places and the planet.

Circular Economy



Consumption and use of natural resources have generally followed a linear approach where materials are sourced, used and finally disposed of as waste.

Arup promotes a ‘circular’ approach instead. We examine upcycling materials using additive robotic fabrication, and the potential of using a waste by-product from the sugar industry on roads in Queensland.

In this section:

[Sugar highways](#) ↗

[Digi-fab\(ulous\)](#) ↗



Sugar highways – Paving our way to more sustainable roads

The Challenge

Large infrastructure projects have many benefits, including business productivity, employment and connecting our communities. However, all too often the design of big road projects is led solely by financial considerations. How can we expand infrastructure outcomes to achieve economic stimulus and more socially and environmentally resilient highway design?

Findings

- Outcome-led design frameworks can drive highway planning conversations towards more rounded benefits, including material sustainability, safety and economic stimulus.
- There is proven potential for sugarcane bagasse ash (SBA) to be an effective neutraliser of acid sulphate soil.
- Using SBA waste by-product from Australia's sugar industry could reduce the carbon footprint of Queensland's road infrastructure.

Sergei Terzaghi

Principal, Infrastructure Support,
Sydney office



Sugarcane

Bio-based materials are becoming an option for the growing circular economy market





Sugar highways — Paving our way to more sustainable roads

Infrastructure is the go-to, low-hanging fruit, for economic growth and recovery. These outcomes are important when grappling with a crisis like Covid-19. But can we push our infrastructure projects to deliver benefits that also contribute to a resilient future for all?

Sometimes, it's the context-specific solutions that drive the most innovative responses and generate both socioeconomic and environmental advantage.

During a conversation with Curtin University, our Australasian geotechnics team, led by Sergei Terzaghi, saw an opportunity to approach a long-standing Australian infrastructure issue in a way that pairs waste with want.

The idea was straightforward: replace carbon heavyweights (like cement mixtures) with environmentally friendly by-products from the local sugarcane industry.

Australian soils along the low-lying east coast are highly vulnerable to acidification.

This weakens infrastructure, particularly roads, and makes it difficult for our engineers to deliver resilient and sustainable solutions. Due to the massive amounts of soil involved in road construction, it's not feasible to replace the contaminated earth, so huge volumes of cement and lime are added as stabilisers. This is not an ideal fix given that ordinary Portland cement accounts for 8% of global carbon emissions, and the production of lime results in toxic elements.



Limestone

The production of lime results in toxic elements.

“Our team has always got an eye out for low-impact sustainable materials that could be used to replace detrimental additives.”

Sergei Terzaghi

Sugar highways — Paving our way to more sustainable roads

Australia produces 35 million tons of sugar each season. The industry is generally viewed as environmentally-friendly because the carbon produced through the combustion process is offset by the carbon consumed during sugarcane plant growth. One of the by-products is bagasse, the fibre left after juice is extracted from the cane. It's burnt to produce steam and electricity, which powers the sugar milling operations. The residue from the burning process is sugarcane bagasse ash (SBA). Some SBA is used as fertilizer in the agricultural industry, but the team is researching its potential for further reuse as an additive to traditional soil stabilising agents.

“An added benefit is that reusing these materials could boost local economies,” Sergei notes. After some preliminary studies, the team moved to Curtin University’s Civil Engineering lab. Here, Curtin’s project lead Dr Amin Chegenizadeh conducted a series of experimental tests investigating how different mixes of SBA and cement affected the mechanical characteristics of the acid sulphate soil.

The team first tested the compressive strength of macroscopic samples that had been submerged in acid sulphate baths. Then, they analysed the micro-interactions between the soil particles, acid sulphate and SBA additions using electron microscopy and energy-dispersive x-ray spectroscopy.



**35
million**

tons of sugar cane are
produced by Australia
each season





Sugar highways — Paving our way to more sustainable roads

Testing provided a lot of information and positive results: with the correct treatment, replacing a portion of cement with SBA did assist in the stabilisation of the acid sulphate soils. And, it's an approach that could work across the globe.

“It can be applied in any location where SBA by-product is locally available, like India and Brazil,” says Dr Mahdi Keramatikerman, the Project Manager who initiated the idea and led the project. “But it has to be localised and regularized because both the SBA and the contaminated soils have specific, potentially unique, characteristics.”

“Another great thing about this project is that it links up with several Sustainable Development Goals. It's a collaborative project, and it takes an innovative approach to reuse materials. And beyond soil acidification, there is a whole range of issues, like adverse clay mineralogy, that this circular solution may help to address” – Sergei

This research shows how Arup is bringing sustainable change and circular economy principles to highway infrastructure. However, creating the touchpoint between a global sustainability agenda and local solution is not simple. To achieve far-reaching resilient outcomes we need clear processes. This is where Arup's Outcome-led Design framework comes in. Claudia Prior, Infrastructure Engineer in our Brisbane office and co-creator of the framework, explains:

“It can be difficult to understand and quantify social and environmental outcomes. The framework gives designers access to metrics and proven design interventions, to which their own work can then be contributed and shared into the future,” – Claudia.

The framework is a database of context-specific indicators, interventions, and metrics that enable users to virtualise the trade-offs between a project's cost, time, economic, social, and environmental benefits. By helping our highway planners and engineers make informed choices based on Sustainable Development Goals, we are now able to build more sustainable highways.

And it's having a real impact across a range of projects. The “Yatala South Interchange Exit 41 upgrade”, in Queensland, used the framework to raise sustainability awareness in early design. This allowed for a smooth integration of green specifications that went beyond the standard requirements, such as using more recycled materials.

What does the future of road infrastructure look like? Can we drive good stimulus through a holistic approach? The road to sustainable, resilient, construction is multi-lane and underpinned by both experimentation and a strong foundation of knowledge. Using circular economy approaches coupled with outcome-led design, we could see issues like soil acidification shift from being a weakness to a positive. One that boosts local economies and provides a beneficial impact so that future generations can travel safely into their future.



Digi-fab(ulous) – the future of construction is circular

The Challenge

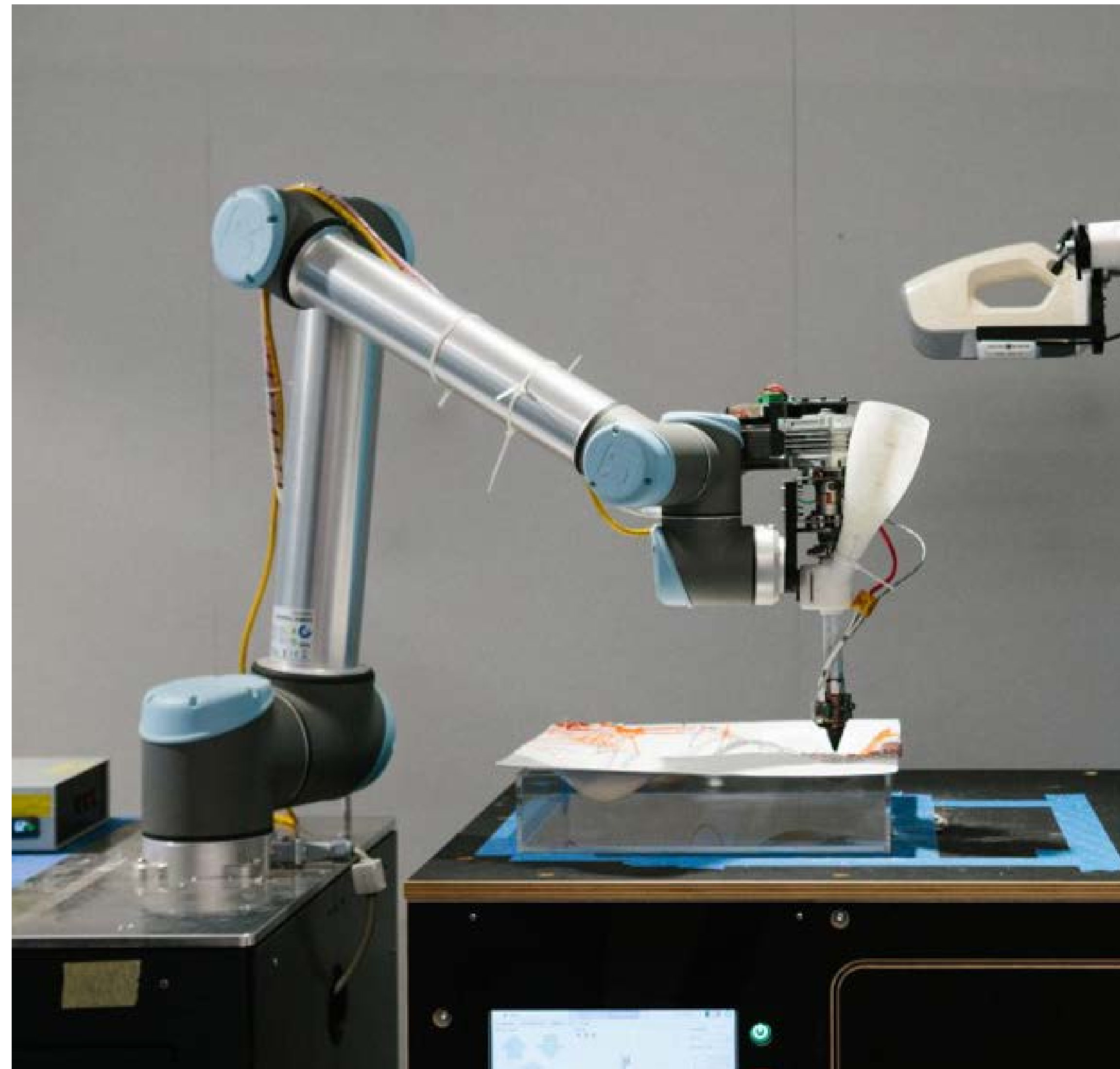
Upcycling materials using additive robotic fabrication creates exciting new opportunities for more circular built environments. But predicting the dynamic behaviour of recycled materials can be a challenge. We're testing the ability of this fabrication technology to deliver efficient and sustainable building practices: from design, to manufacture, to construction.

Findings

- Digital additive fabrication paves new pathways for the construction industry to embrace the circular economy.
- Affordable sensing technology can be coupled with upcycled supply chains to achieve material, component, and whole building resilience.
- Digital design and fabrication open new practical architectural and design possibilities, from procurement to material form.

Haico Schepers

Principal, Buildings Group,
Australasia



Robotic 3D printing

Additive Manufacturing transitioning
from academia to industry



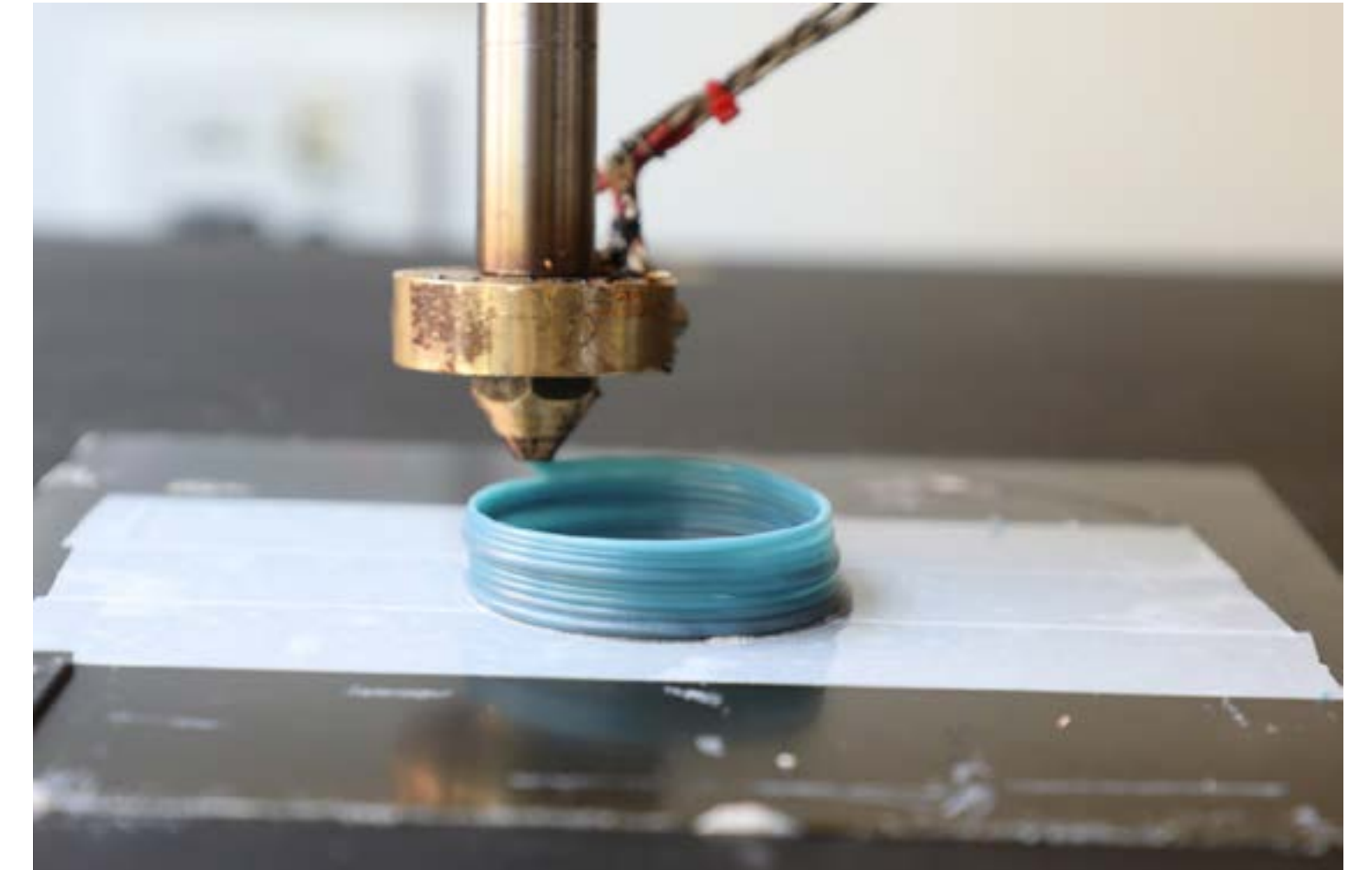
Digi-fab(ulous) – the future of construction is circular

The construction industry is currently worth 7% of Australia's GDP. It's not all good news, however, with evidence of flat productivity, increasing waste and ongoing skills shortages – as well as a solid 39% of accountability for global energy emissions.

With [Industry 4.0](#) underway, we have an exciting opportunity to address these industry challenges by bringing together digital smarts and a sustainable outlook.

[Designing with digital fabrication](#) looks to be the key element. “Digital fabrication has the potential to rejuvenate the building industry,” says Andrew Weetman, an engineer in our Sydney buildings team and leader of a collaborative research project between Arup and the University of Technology Sydney (UTS).

While exploring the connection between digital fabrication and sustainable design practice, the team came up with the idea of developing an intelligent façade system made of recycled materials. The project, based on circular economy principles, soon gained momentum and was chosen for investment as part of Arup's Global Research Challenge award.



Digi-fab(ulous) — the future of construction is circular

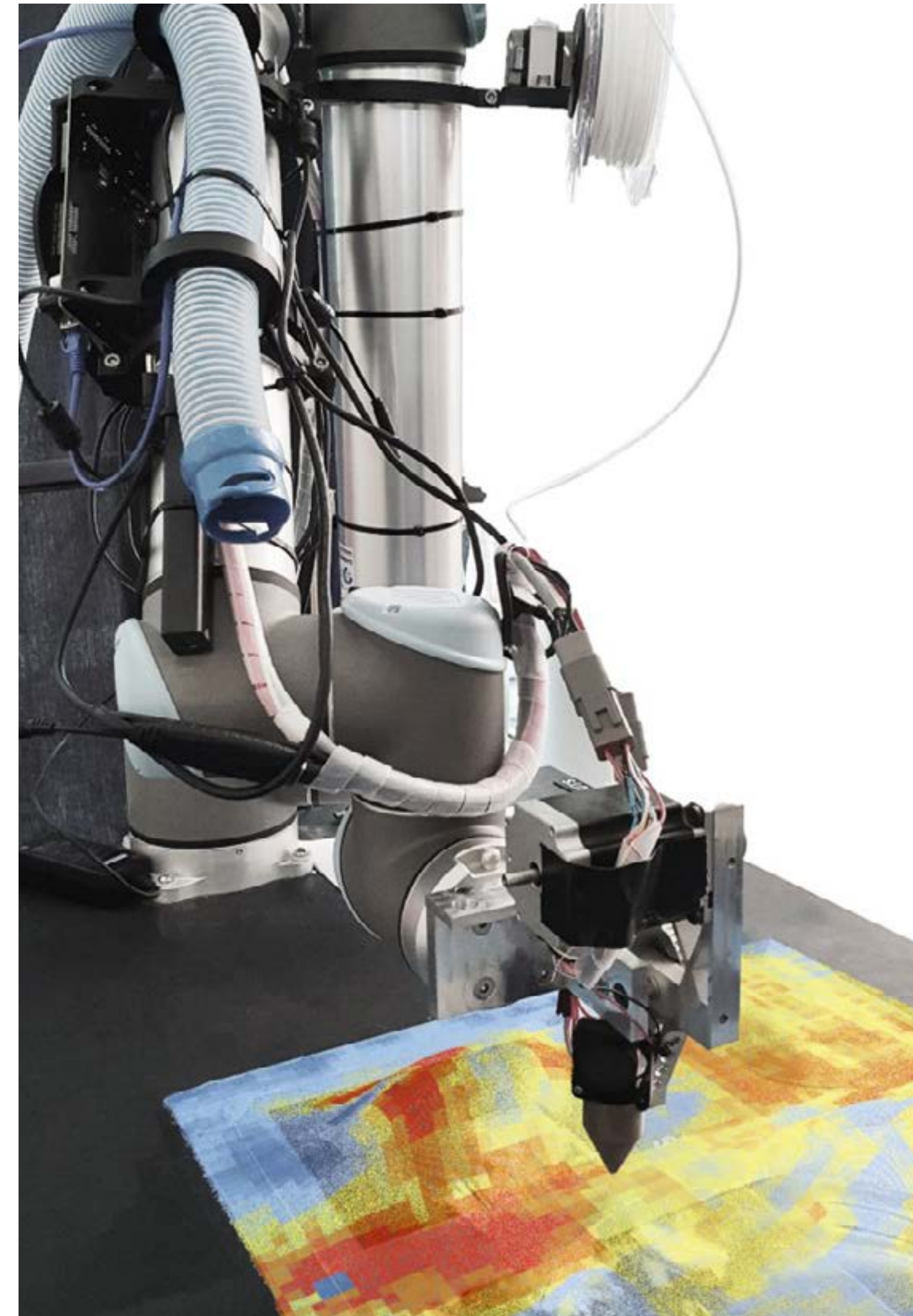
The concept is, at base, very practical: use off-the-shelf sensors to hack a 3D printing robot to deliver real-time manufacturing. For a real-world example, take a builder who discovers during construction that there's a flaw in the bracket design. Today, they'd have to decide between replacing the flawed items with a second-rate product or spend more time and money to rectify the variation. In the future, they could use a sensing robot to scan the problematic part of the building, fix the design, and print the brackets using material recycled from the original defective items.

“Combining sensing technology with digital fabrication enables scalable design responses. Currently, we have to apply the safest and most conservative load to an entire building.”

“These emerging approaches give us
bespoke solutions for each build,
opening possibilities for saving errors,
materials, and ultimately money.”

Andrew Weetman

To get an integrated solution, the team tested sensing and robotic manufacturing across construction scales: the micro (materials), the meso (components), and the macro (entire building).





Digi-fab(ulous) — the future of construction is circular

For materials, the team used the labs at UTS to test options that performed well for 3D printing and structural purposes. “Some recycled materials like aluminium have a lot of variability. In our case, plastic is quite homogeneous, but finding the right mix and quality control process took some trial and error,” says Andrew.

The team then focused on prototyping a façade panel component. First, they gave the robotic sensor the panel geometry. Using an AI generative model the robot learnt how to lay plastic autonomously along the panel’s stress trajectories. “Real-time sensing would inform where to lay plastic filaments next, closing the design-to-construct feedback loop,” says Associate Professor Tim Schork from the School of Architecture in the Faculty of Design, Architecture & Building and leader of the UTS team.

“Then at the building-level, we can go one step further and embed real-time sensing within the 3D-printed panel itself,” says Andrew. “This could capture data to inform predictive building maintenance or improve future design iterations.” The team is now taking the project to a living lab installation to test the prototype’s performance in real-world settings over time.

It’s important, however, to ensure that when solving one problem we don’t create another. “There are so many positive opportunities and we endeavour to only use plastic when we can source it as a waste product from another process – so we are essentially upcycling or reusing, without creating another market for plastic with perverse outcomes,” says Deepika Jaduram, Engineer in our Melbourne Environment & Resources team, who is overseeing sustainability on the project.

As well as working towards a circular economy, the approach opens exciting new architectural and design possibilities.

“Robotic manufacturing allows us to make fabricate free-form geometries, instead of being stuck with extruded geometries. And with robotic printing, you’re not constrained by economies of scale, which could expand the material repertoire of the built environment,” says Tim.

By coupling digital design with upcycled plastic (or other materials) using sensing robots, we have real potential to achieve net-zero by 2050. And in doing so, we not only transform our built environment into an adaptive and resilient entity, we also revitalise the construction industry and bring it into the circular economy.



Covid Response



After a crisis comes recovery. We've all had to rethink, adapt and recover from the pandemic. This is a chance to address longstanding issues, solve new problems and revisit opportunities.

We've explored new and digital responses particularly looking at experiences of public spaces, ranging from hawkers markets in South East Asia, to urban spaces and sporting venues.

In this section:

[Seeing the future](#) ↗

[From tactical to strategic urbanism](#) ↗

[Meet the Hawkers](#) ↗



Seeing the future: making safer public spaces through computer vision

The Challenge

Covid-19 has changed our perception of safety and public places. Spatial planning is getting more sophisticated, largely due to advances in Artificial Intelligence (AI) and data analytics. We tested some of the emerging technologies to support a confident and safe return to public places.

Findings

- How computer vision and AI tools can help us design a safe return to public spaces.
- Understanding the relationship between data sets, design decisions, and ethics.
- Why computer vision systems require a combination of expertise across digital, urban design, transport planning, resilience security and risk.

Stephen Lynch

Senior Consultant, Advanced Digital Engineering,
Melbourne office





Seeing the future: making safer public spaces through computer vision

Imagine a 70,000 seat stadium. There's a big game on. Covid-19 is still wreaking havoc but amazingly supporters can still get in and out of the venue, safely distanced, using AI-generated routes delivered via an app on their phone.

As our cities grow in complexity we are constantly facing new challenges. New tech tools promise better and faster solutions, but it's vital to be confident that the tools are up to the task, especially when safety is at stake.

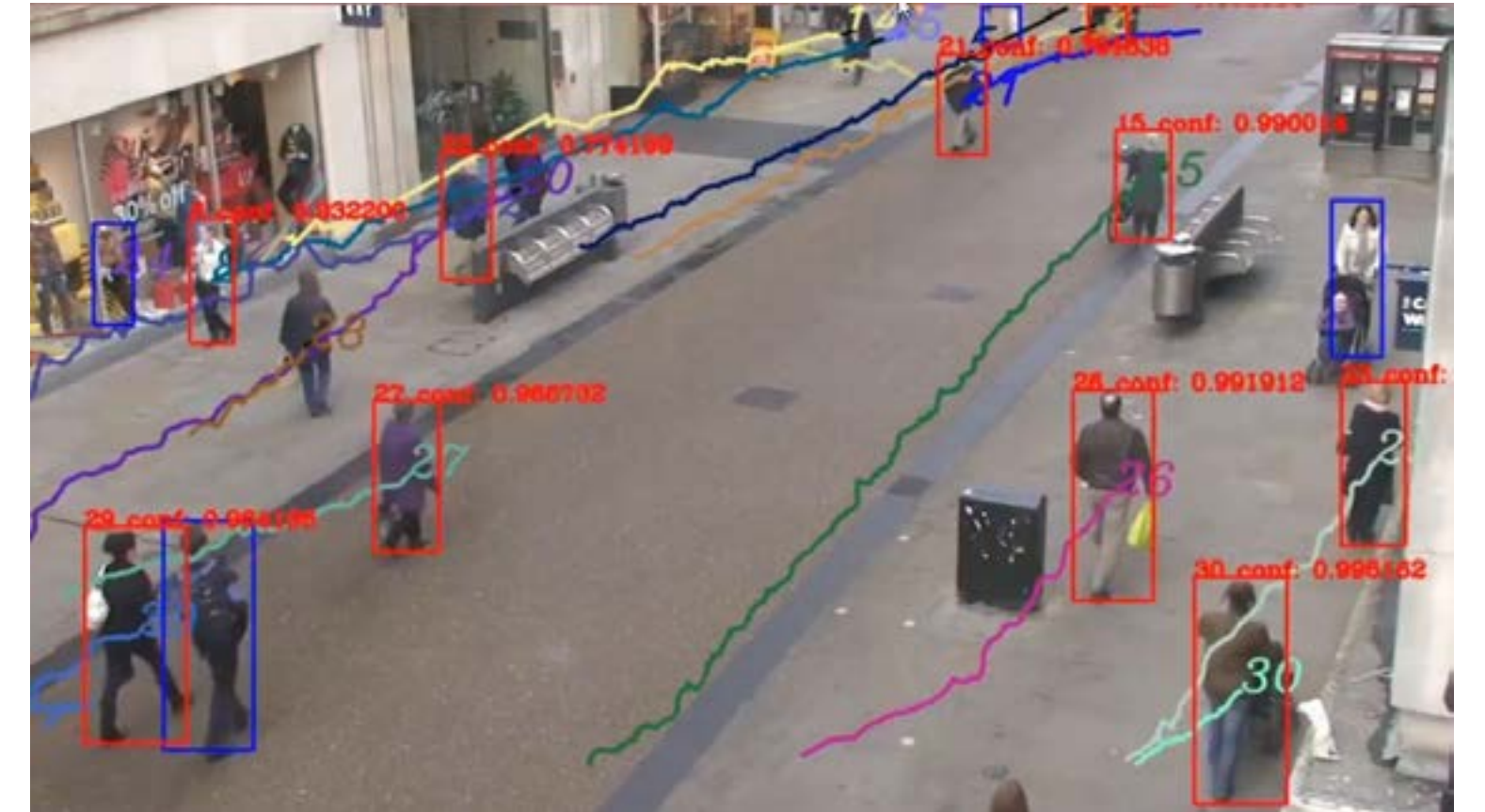
Our Advanced Digital Engineering team has taken a look at available AI and

computer vision technology and how this can support better spatial planning. Data is becoming central to the design of [how our cities move](#), especially in light of Covid-19. This is no news at Arup.

Our [Mass Motion](#) pedestrian modelling software is already assisting the return of people to public space and office buildings. By combining people flow and social distancing criteria, this tool highlights where to implement design responses to transition to a safely-distanced new normal.

But to ensure the quality of any output simulations, you need quality input. The data has to be good! Before jumping on any design intervention, an understanding of how people use the space in the real world is required.

One of the post-Covid-19 challenges will be bringing people back to mass movement spaces like train stations and stadiums. This means counting passers-by through key transit zones like entries and exits, at different times of the day, on different days of the week. Doing this manually is difficult and takes huge amounts of person-hours.





Seeing the future: making safer public spaces through computer vision

So, it's no surprise that the market is now flooded with computer vision solutions. Whilst they make life easier, they can also be very costly. "A client may not want to be locked into a particular vendor. One of Arup's strengths is to be independent thinkers, allowing us to advise our clients bias-free on their best way forward," says Stephen Lynch, Senior Consultant in the Advanced Digital Engineering team. "We wanted to better understand the options for our clients to close the loop between simulation and real-life data. One aspect we've been looking at is the difference between creating an open-source solution versus an off-the-shelf vendor."

The team shortlisted and tested a range of available tools. Starting with how data can be stored, they quickly ruled out cloud-based solutions due to their high cost. They then loaded a few open-source tools onto local machines. "This took longer than we expected," laughed Stephen. "It was one indication of the benefits of leaving such complexities to an established vendor!" But on the flip side, open source solutions enable you to build your own customised framework, and there is a huge community constantly improving the software. "I definitely see ease-of-use of this technology developing, and fast," adds Stephen.





Seeing the future: making safer public spaces through computer vision

The experiment highlighted key considerations when looking for a solution, be it open-source or an established vendor off-the-shelf option. Firstly, all AI tools require good data sets to operate, which means that data collection must ensure appropriate quality, quantity, and diversity. Then there are the flow-on aspects of where to store the data set, where to run the analysis, and how much computing power will be required. It's important to know and understand all these elements before deciding which approach to take.

“We need to empower clients with the right questions to ask. Is the data open or proprietary? Where will the data be stored? Do I have access to the data? Is it encrypted, or sensitive?”

Stephen Lynch

“This enables our clients, giving them an understanding of how things will be done, how long it will take to get a result, and what they are getting for their money,” – Stephen.

There are, of course, other significant factors around data ethics, safety and privacy that must be considered. “Whilst we were working on this project, the creator of the YoLo algorithm retired, citing ethical concerns around advanced facial recognition technology,” says Stephen. “All facets have to work together.”

We already live in smart cities. And our Melbourne work on computer vision tools has been included in a current bid for New York’s Grand Central Station alongside contributions from experts in urban design, transport planning, security, and risk. As Mike Bloomberg, former Mayor of New York City, famously said: “In God we trust. Everyone else bring data.”

To ensure effective evolution of smart cities, we need to keep ethical concerns central, and we need best practice strategies to manage the various aspects of governance, planning, and delivery. But getting it right will reap huge benefits, especially for transport.

AI and computer vision are complex technologies and touch on complex issues. These solutions transcend conventional engineering disciplines, requiring the combination of ethical and technical expertise. But the unprecedented challenges we are facing require new ways of thinking. AI is now crucial in thinking how we create safe public spaces. And we should use it – carefully – so that even a pandemic can’t stop us from attending our favourite sports match!



Stephen Lynch

From tactical to strategic urbanism: turning meanwhile-use into long-term change

The Challenge

Tactical urbanism has become a go-to for quick testing of new ideas in low-risk environments. With COVID-19 bringing our cities to a halt, usual bureaucratic processes have increasingly been replaced by dexterous tactical responses. We studied the elements needed – from governance to evaluation – to enable long term, equitable, and community-oriented change.

Findings

- How to embed tactical urbanism in long-term planning.
- A progressive approach to tactical urbanism means adopting its original spirit – community action for better places.
- The sweet spot lies with projects that have both a strategic future and an engaged local community.

Penny Barnes

Senior Designer, Advisory Planning & Design,
Melbourne office



Pop-up dining

Activating streets during Covid-19





From tactical to strategic urbanism: turning meanwhile-use into long-term change

Virus-led disaster films like ‘28 Days Later’ and ‘I Am Legend’ provoke us by depicting radical change to urban environments. Watching these catastrophic scenarios, we often ask ourselves: “what will happen on these deserted city streets now?” With Covid-19 we’ve been taken beyond these pop culture tropes to experience the actual eeriness of empty streets. This new reality has also posed the ‘what now?’ question for governments and businesses. Adjusting to this new normal, we’ve seen a rapid uptake of tactical urbanism approaches to adapt and improve our built environment.

“But does it really take a pandemic to make these changes?” asks Penny Barnes, Urban Designer from our Melbourne office. Penny teamed up with Greer Oliver, Urban Designer from our Auckland office, to find and package some answers into a toolkit for our city planners: [Tactical Urbanism and Urban Governance](#).

For decades, tactical urbanism has been used by communities wanting to address and equitably deliver where governments and markets may fall short.

Targeting issues around transport, public space and, increasingly, climate change, tactical urbanism instigates change through temporary, low-risk and reduced cost urban interventions. This approach often sits in opposition to traditional planning approaches, which are generally large-scale, slow, and expensive with outcomes that can end up drifting away from the needs of the communities they impact.

“Covid-19 highlighted the rigidity of our traditional bureaucratic planning processes, and their inability, often, to deliver sensible benefits quickly and at low cost.”

Penny Barnes

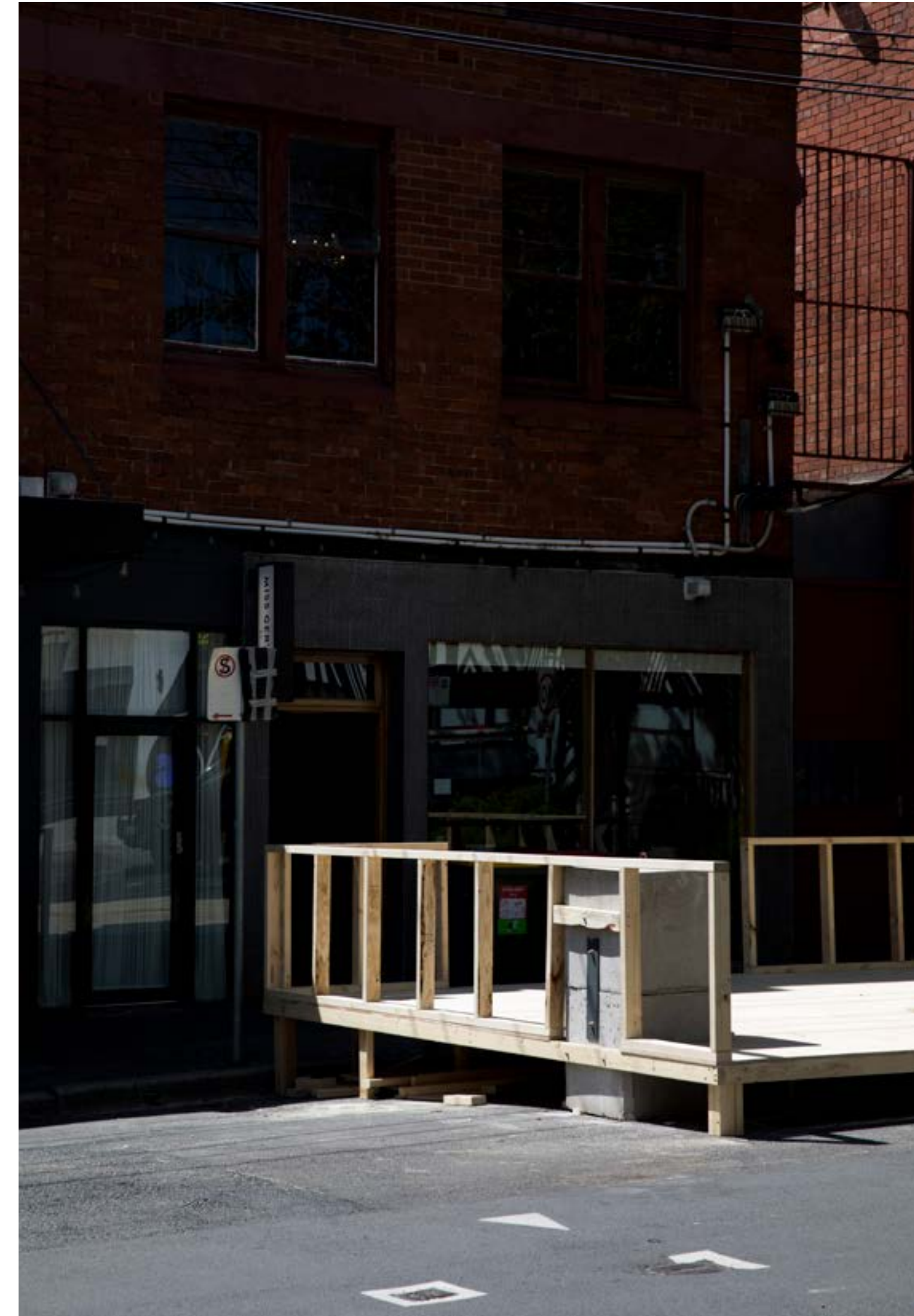


From tactical to strategic urbanism: turning meanwhile-use into long-term change

Arup has a strong background in this field, from [London Fitzpark](#) to [Daylighting Melbourne](#) and [Towards Superbia](#). Still, the team realised they needed to look at the broader context beyond single pop-up projects. Sitting alongside our other work on [Tactical Urbanism](#).

This report investigates how tactical urbanism can enable long term strategy and more equitable benefits. “Through this research, we wanted to understand how governance and evaluation can play a role in achieving more lasting and equitable changes, at both small and large scales,” Greer says. “Since we wanted to reduce the risk involved in decision-making, we set up a clear framework that connects tactical options and benefits.”

To provide a way to link with a city’s broader strategic agenda, the team identified seven key functions of tactical urbanism: creating vibrant places, prioritising safe environments, engaging communities, driving local economies, connecting through transit, supporting active travel and reducing environmental impact. So, for example, by investing in improved pedestrian movement, you can encourage shifts away from private vehicles. Or, by increasing active travel, you can improve public health, air quality, and a sense of local belonging.





From tactical to strategic urbanism: turning meanwhile-use into long-term change

“The functions were drawn from a series of case studies,” says Greer. For instance, before Covid-19, the Auckland Council trialled replacing on-street parking with temporary footpath extensions. This High Street pilot was the first step in the “Access for Everyone” programme, a key component in the Auckland City Centre Masterplan to reduce the number of private vehicles in the city centre and create a more people-focused and equitable environment.

“Having clear priorities for a city coupled with transparent decision-making pathways can dramatically improve a planning system”

Penny Barnes

More examples came up in Melbourne, where local councils relaxed their legislation to support businesses throughout lockdowns. “Pre-Covid, cafes would struggle to even get a permit to trade through an open window,” says Penny. “Now we see pop-up cafes reclaiming car parking spaces all over the city. How good would it be if this flexibility could become the norm?”

As tactical urbanism projects operate within a huge range of unique contexts and drivers, under normal non-Covid

circumstances it can be difficult for councils and governments to know where to start. The research team drew out common success factors, from storytelling and messaging, to relationship building, accessing alternative funding pathways, and building capacity across governance, implementation and evaluation.

“It’s hard to pin down a prescriptive delivery method or approach,” says Greer, “but there are some essential elements that underpin the success of projects, no matter who the owner is, or the scale of the project.” This is what lies at the heart of the [implementation toolkit](#): linking strategic functions with project tactics and success factors. “This is where we see the activation of empty shops and car parks driving local economies. Or temporary wayfinding interventions facilitating, in a playful way, the first- and last-mile journeys, contributing to improved safety for pedestrians and enhancing access to local business,” says Penny.

Unlike Hollywood disaster films, we are already seeing a re-population of our streets. We’ve also seen how local councils can be quick to test low-cost tactical interventions. With growing research and evaluation, these flexible approaches can be better recognised and feed into future strategy making, to bring communities more adaptable, relevant, and equitable outcomes.



Meet the Hawkers: framing a new normal in Singapore

The Challenge

Singapore is one of the most densely urbanised nations on earth. Public space is where Singaporeans eat, meet and socialise. This vibrant street life is key to community identity and function. But high density brings high risk in a Covid-19 environment. Our Singapore office launched a design competition to creatively solve some of these critical real-world problems.

Findings

- As physical distancing continues, there's an immediate need to rethink and reshape shared spaces in our cities.
- Arup Singapore devised a virtual competition to mitigate the impact of Covid-19 on Singaporean street culture.
- How digital tools and design thinking combine to help us devise a new normal for public spaces.

Jinfeng Xu

Principal, Technical Specialists,
Singapore office



Hawker Centers

Are at the core of Singaporean street culture





Meet the Hawkers: framing a new normal in Singapore

Singapore's streets bustle with people socialising and conducting commerce. Like many densely populated Asian cities, street life is a core part of Singaporean cultural identity. In 2020, UNESCO added Singapore's vibrant hawker culture to their list of [Intangible Cultural Heritage of Humanity](#). But in the same year, Covid-19 brought this communal experience to a sudden halt, threatening the city's grassroots cultural identity.

While adapting to lockdown restrictions and remote working, our Singapore office launched a fully-virtual design competition to devise a new

normal for Singapore streets. The internal competition focused on how to combine design interventions and digital technology to ensure safe public spaces.

"I really missed the environment of people walking together and talking together when we started remote work," says Jingfeng Xu, Singapore office Principal and leader of the initiative. "Because Arup has some of the best people in the industry, we wanted to create a platform to bring together our interdisciplinary strengths and address the Covid-19 challenge with creative solutions."

With the aim to think and design without boundaries, the competition also became a great benchmark for Arup to test the look and feel of an entirely virtual creative process, from the workshops and briefing right through to the judging and award ceremony. Participation numbers were deliberately limited to keep the project focused and agile. "Our broader aim was to use Singapore as a test case to see how the process worked," notes Jingfeng.



The winning research team

Meet the Hawkers: framing a new normal in Singapore

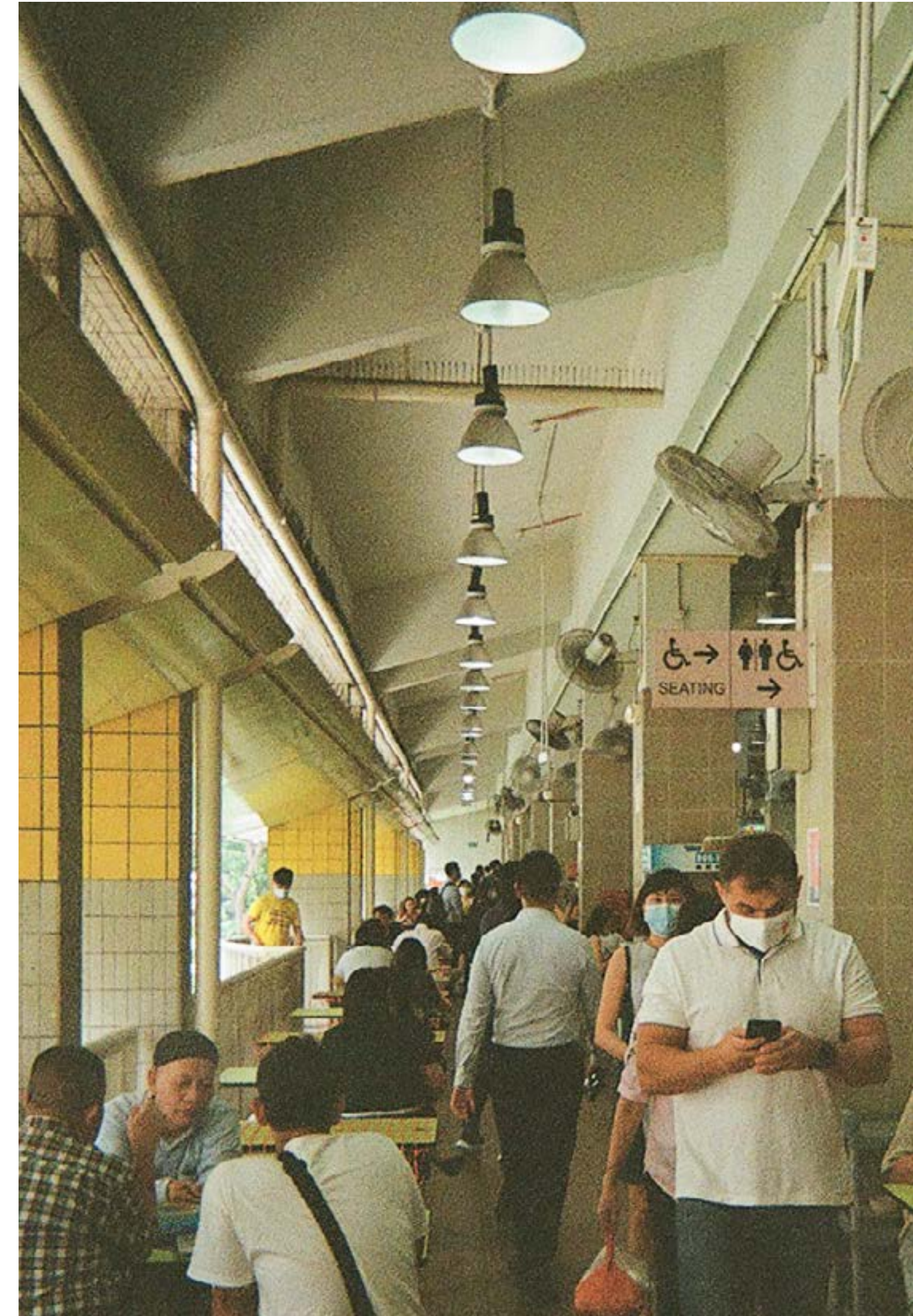
Twenty people from a range of disciplines were formed into four teams. Each team included a ‘digital guru’ and a ‘bigger picture mentor’ to encourage the cross-pollination of design and digital solutions. After selecting a unique public-space problem to solve, the competition was on! With a mix of expertise and experience, each team was challenged to use available resources, technology, and environments as efficiently as possible.

“This initiative from the Singapore office was a stroke of genius; a friendly competition to harness the innovative powers of our people resulting in winning ideas that might be developed as a service offering.”

Veng-Wye Tong

“All this in lockdown mode with teams collaborating from home creating ideas using and based on technology for urban adaptations necessitated by the pandemic. Worth replicating!” – Veng-Wye Tong, Australasia Regional Board Member.

The winning proposal addressed a backbone of the Singaporean public space: the hawker centre. These busy, bustling, communal environments are a staple of Singaporean culture where people from all backgrounds come together to chat, play chess, busk, but most importantly: eat! When Covid-19 hit, shifting to take-away only worked as an immediate short-term response, but is a terrible longer-term answer to physical distancing guidelines.





Meet the Hawkers: framing a new normal in Singapore

The team proposed a booklet of design solutions to adapt the experience of dine-ins and meet safety standards. Key to its success was a combination of Arup's design thinking and digital expertise. By leveraging Arup's Space Explorer, a people movement simulator, they could safely manage human traffic. Their concept not only provides a safer way for people to enjoy their meals in the company of others, but also facilitates business recovery.

“As social physical distancing continues into the imminent future, there's an immediate need to rethink and reshape shared spaces in cities.”

Fergal Whyte

“Through design, we can help fill the regulatory and technical needs to control, manage and convert spaces quickly and effectively in a crisis.” – Fergal Whyte, Arup Board Member and Chair of South East Asia Executives.

Picking up on the theme of converting public spaces quickly, the runner-up team addressed the future of local shops and urban logistics. They proposed a centralised delivery hub system and safer, more flexible delivery models for goods like groceries, food, and e-commerce. Inspired by the dynamism of

‘mobile hawkers’ from the old days of Singapore, the proposal consolidated parcel lockers into suddenly-disused public spaces and multi-storey carparks, temporarily revitalising strategic parts of the city.

Both teams presented their concepts to Singapore's Urban Redevelopment Authority, which led to the creation of a collaborative working group. “We have created a new, multi-disciplinary, light-touch approach to coming up with new ideas for wholistic solutions to real-world problems,” says Jingfeng. “The process succeeded because it had strong guidance and support through all levels of the organisation: it connected people across Arup's various strata. And it was fun!”

Covid-19 has dramatically disrupted the vitality of our public space cultures. And this major health crisis can't be solved by narrow technical solutions. Returning to communal tables filled with food and laughter will take some smart solutions. Just as the hawker centres evolved through the mixing of diverse cultures, we need to think across systems and functions to deliver resilient, scalable and community centred solutions that meet our city's needs. Here's to a delicious future!



Resilience



Today, society's ability to thrive can be compromised by risks from climate change to infrastructure deficit, from population growth to pandemics.

More people than ever depend on businesses and critical infrastructure systems working together. We look at resilience interventions with examples from urban food in Singapore to asset flexibility and mine reuse.

In this section:

[Circular bites](#) ↗

[Flexing our assets](#) ↗

[Mining change](#) ↗

[Supplying resilience](#) ↗



Circular bites: reworking our urban food ecosystems for city-wide resilience.

The Challenge

The events of 2020 threw food security into the spotlight. Our Singapore office has been studying ways to make cities more food-resilient, using the nation state as a test-bed for an Urban Food Production Masterplan.

Findings

- Singapore's small, highly-populated footprint provides an excellent test-bed and benchmark to explore new approaches to urban food production.
- Achieving long term urban food security requires circular design principles across systems of energy use, water, waste, industry and employment.
- From high tech production to community gardening, cultural and social changes will be required as new food production processes come to fruition.

Chintan Raveshia

Associate Principal, Advisory Planning & Design,
Singapore office





Circular bites: reworking our urban food ecosystems for city-wide resilience.

Singapore is a small and highly urbanised state and imports 90% of its food. This reliance on imports makes it particularly vulnerable to shocks and stressors like Covid-19 and climate change. However, this challenge isn't faced by Singapore alone. With 68% of the world's population projected to live in urban areas by 2050, Singapore is already dealing with problems many other cities will face in the next 50 years.

“I was shocked to discover that 50% of the planet's habitable land is used for agriculture, and two-thirds of that goes to meat and dairy livestock.”

Chintan Raveshia

“On top of that, agriculture uses 70% of the world's fresh water. In a climate emergency, we must start managing food more sustainably.” – Chintan Raveshia, Cities Planning and Design Leader, Singapore.

To address the issue, Singapore has introduced a target to generate 30% of its food locally by 2030. Helping to make this ambition a reality, our Singapore

office has been working with stakeholders like the [Centre for Liveable Cities](#) to understand the changes needed. The results, collated in [The Urban Food Production Masterplan Framework](#), is a world-first piece of research that maps Singapore's current food ecosystem and explores future scenarios to reach the visionary '30 by 30' goal.



Urban farming and agriculture

An indoor greenhouse in Singapore.

Circular bites: reworking our urban food ecosystems for city-wide resilience.

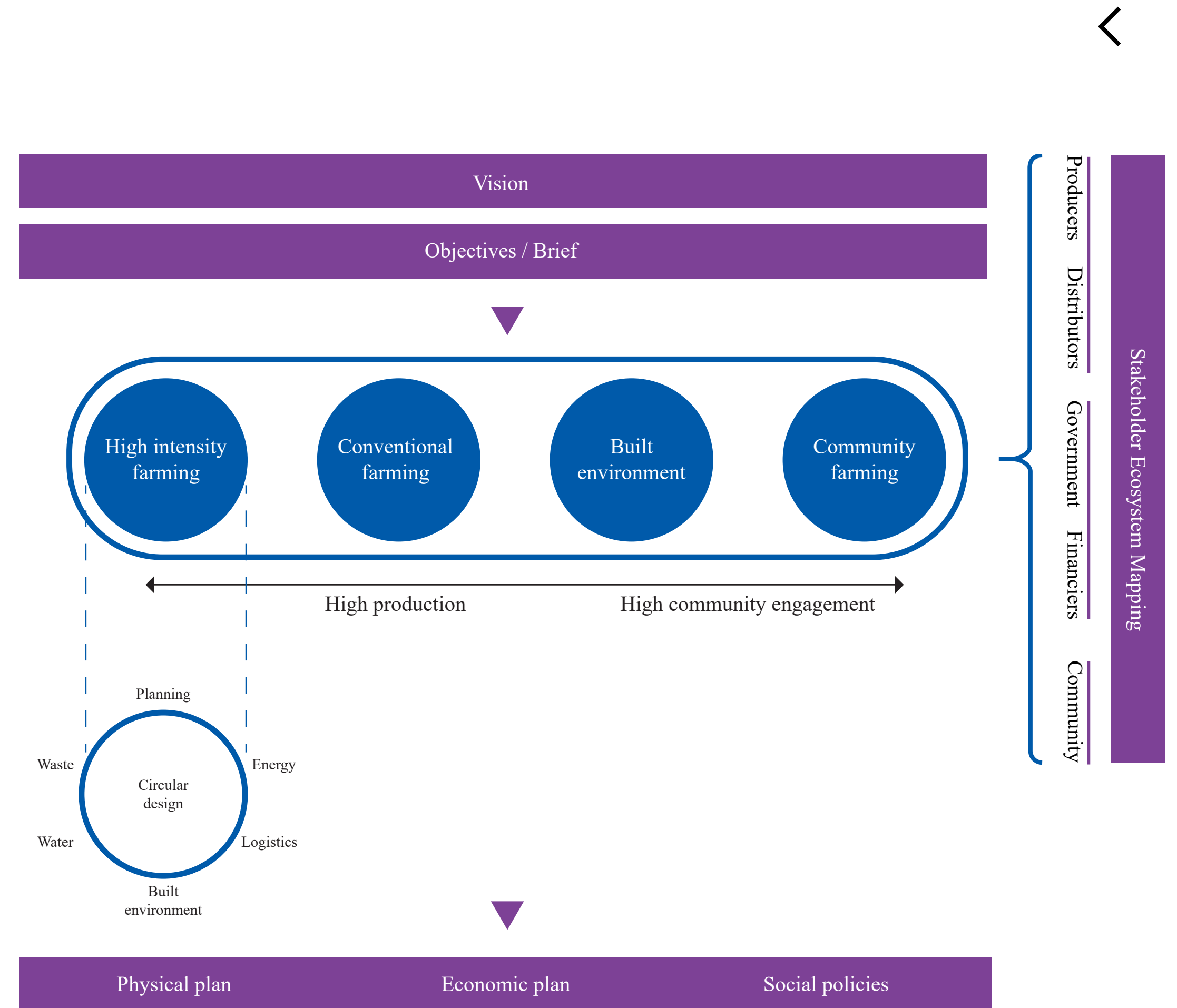
“The masterplan is ambitious,” says Chintan. “It addresses the problem from a country-wide perspective, looking at food supply across the spectrum: from large-scale production to market gardens. But beyond that, it’s a framework designed to be a practical manual for implementation.” Using Singapore as a benchmark, the report highlights how resilience and food security are deeply entangled globally.

To address this link between resilience and food security, we need to match resource requirements around space, water, electricity and transport with goals around city resilience, zero-carbon and the circular economy. How do we help our decision makers and city planners make the transitions needed? The Framework developed by our team includes a series of design interventions, planning guidelines and policy advice that is economically, socially and environmentally feasible.

Fortunately, we already have many advanced tools at our disposal. The work is in linking them up. For example, urban vertical farms use 70% less water than conventional farming. Digital tools can connect vertical farms with marketplaces and provide better tracking of store shelf life to create a more efficient supply chain.

“Implementing new logistics for waste, water and tech, creates holistic industrial estates that enable circular manufacturing. It’s this multidisciplinary approach, this ecosystem, that can solve many of our problems. Like bringing an energy specialist together with a food lab technician.”

Chintan Raveshia



Ecosystem mapping Stakeholders and policy diagram



Circular bites: reworking our urban food ecosystems for city-wide resilience.

New supply chains that replace environmentally intensive foods like beef and chicken will bring huge benefits for the planet and its ecosystems. Arguments about what is and is not healthy to eat – like the fuss around the Impossible Burger – will likely rage on. But there are demonstrable environmental benefits, like better land use and reduced greenhouse gas emissions, associated with guilt-free, ethically-minded cultured “happy meats”. These cultured meats do, however, require a lot of water. This is where a country with a strong start-up environment, like Singapore, can bring agricultural tech, water and energy specialists together to solve these problems and contribute to changing our food culture and social expectations.

It’s likely that some people will have reservations about new sources of protein or fibre. Fostering a deeper understanding of what’s required to grow food can help with making the transition. “There is work to be done to enable people to take the changes on board,” Chintan says. “People will be more willing to give-up year-round access to a seasonal fruit like apples if they have a better understanding of the broader context.”

On this front, the Framework looks at the importance of enriching people’s immediate relationship with food production. For example, having children helping to water and weed a community garden alongside their grandparents builds an understanding of food generation as well as social connection and community spirit.

The Framework addresses a global problem by offering local solutions. It also meets Sustainable Development Goals, including SDG 2: Zero Hunger via sustainable food production systems and resilient agriculture, and SDG 12: Responsible production and Consumption, to reduce food losses along production and supply chains, including post-harvest losses.

Following testing in Singapore, the team is already working to bring it to other cities like the new capital of Indonesia. With climate change and population growth likely to catalyse global change in land use and food production, we’ve ensured that the Framework also applies in less dense countries with more direct access to land. It’s no wonder countries like Australia, already experiencing a change in arable land availability, are expressing interest.

If we act now, we can improve our policies and social perspectives to enable urban food production before our cities reach a crisis point. As a collective, we have an opportunity to implement new ways of providing food security and in doing so increase resilience through a more integrated and circular approach to water, electricity, and transport connections.



Flexing our assets: rethinking asset flexibility for better resilience

How do businesses remain truly resilient when their business continuity is disrupted? Covid-19 fractured many business activities, leading to workaround solutions such as street dining for restaurants and the need for cost-saving measures, such as shutting down segments of airports. As experts in the built environment, we wanted to expand these quick-fit responses to include longer-term outcomes. We developed a decision-making tool that analyses how infrastructure assets can generate the greatest ongoing value during short-term shocks and long-term stressors.

Findings

- Separating business continuity from asset continuity can drive resilience and value generation.
- Using an outcome-led approach to define the value of a business and its assets before its purpose generates a greater set of adaptive possibilities.
- A transparent and auditable decision-making process aids strategic planning and asset resilience.

Alice Vincent

NSW Lead, Resilience, Security & Risk,
Sydney office



Empty airport car-park
An opportunity to re-think its function





Flexing our assets: rethinking asset flexibility for better resilience

Should an airport be used solely for aviation? Under normal circumstances, this seems like a rhetorical question. But when shocks like Covid-19 hit, leaving kilometres of runway deserted, it becomes entirely sincere. Alice Vincent, lead of Resilience, Security & Risk for NSW, took on the challenge with Kaitlin Shilling from International Development and Nic Justin from the wider Technical Specialists Group. This multidisciplinary team looked at the problem with our clients to help them better

understand the difference between business continuity and asset continuity.

From here, Alice and her team developed the “Asset Resilience Assessment tool” (or ARA), an auditable decision-making framework. The framework informs the types of flexible uses an asset can provide in order to realise greater ongoing resilience. This means mitigating risks we can identify today, and having tools for ‘adaptability’ that may be needed to thrive in the face of future unanticipated events.

So, how do you make infrastructure assets continuous despite severe business suffering? You divorce the asset from its original purpose. For infrastructure assets, qualities like redundancy and robustness have traditionally been prioritised over flexibility. By flipping the redundancy and robustness equation to focus on adaptability, we empower asset owners to easily identify repurposing options and their implications. This determines which assets are flexible, in what way, and over what time frame.



“The research started when we saw how Covid-19 ground so many businesses to a halt. Having previous experience with airports, we saw how large airport operations and revenues were stopped in their tracks. So that’s where we started.”

Alice Vincent

Flexing our assets: rethinking asset flexibility for better resilience

“The ARA takes resilience as a positive, future-looking strategic enabler,” says Alice. “By defining the value of the business (and its range of assets) before their purpose, we’re able to identify a greater set of possibilities. We’re able to get a better match between the business assets and the functions they can perform to generate the values the client aspires to.”

For example, the purpose of an airport is to get passengers from place A to place B. The value of an airport includes creating employment, generating income and providing a service to the community. Airport buildings and other physical assets can still be used to achieve these business values.

After identifying the values of the business and its assets, the tool is used to create a stocktake of existing space, facilities and resources. It then breaks them down into component parts like staff skills, IT, co-tenants and stakeholders. The value and stocktake are mapped against criteria, which are informed by market and societal needs.

For example, an airport consists of hangars, car parks, hotels and service staff, amongst other things. In a pandemic-recovery scenario, hangars can become warehouses and logistics facilities, car parks can become drive-through cinemas, and airport hotels can be used for quarantine centres or vaccination clinics, taking pressure off normal healthcare clinics.





Flexing our assets: rethinking asset flexibility for better resilience

But it doesn't stop there. The ARA can be applied to a swathe of industries. University campuses, office buildings and retail spaces could all be assessed using the ARA to determine the best-use options across a range of temporal lenses. A university campus could in the short term adapt its sports facilities to be community hubs or collaborative workspaces or over the longer term adapt its car parks to be indoor farms.

With shocks like Covid-19 and climate change, this outcome-led approach is becoming [increasingly relevant](#) and necessary to gain a competitive advantage. It also dovetails with our other work on resilience, like the Supplying resilience – the future of Australian logistics and the [City Resilience Index](#).

By having a transparent and auditable decision-making process, we can expand our understanding of both business and asset resilience and, most importantly, we can empower asset-owners to decide which new or alternate functions the asset would be most suited to. We want to help clients rethink their assets beyond traditional business continuity to embrace a more resilient concept of continuity. This is an agile way to future-proof our cities against external conditions, be they short, medium or long term.



Mining change – from the future of mines to the future of communities

The Challenge

Forward-looking governments worldwide are taking coal off their agendas. In Australia, taking coal out of our energy equation requires rethinking the future of both the assets and their communities. We studied how the transition away from coal could serve community needs and create new economic opportunities through adaptive reuse of mines.

Findings

- To successfully pull out of coal, it's critical to fully understand the possibilities and benefits for both the mining sites and the mining communities.
- There are ever-increasing global precedents for the successful transition of old coal-fired power stations and mines into new functional entities.
- Successful adaptive reuse that delivers benefits unique to each location combines localised knowledge, engineering expertise, community engagement, and strategic planning.

Michelle Cottrell

Associate, Advisory Planning & Design,
Brisbane office





Mining change – from the future of mines to the future of communities

We know from the data that our planet is heating up. To avoid catastrophic heating, we need to act now and decarbonise our economy by 2050. Energy decarbonisation plays a central role in the transition and governments worldwide are taking action. Australia must do so too. Our current energy supply is almost 80% fossil fuel, and most of it is produced in old, inefficient coal-fired plants that are operating well beyond their intended 40-50 year lifespan.

With the cost of renewable energy dropping, private and public sectors are seeking ways to promote a sustainable energy transition whilst also figuring out how to address the local social and economic impacts of shutting a community employer. Most state governments have set up proactive policies around mine closures. Some currently require existing mines to produce a rehabilitation plan to continue operation, others require financial securities or full closure plans. However, the overall strategy is not always clear, particularly for the communities most immediately affected.

Arup has already assisted agencies [across the globe to strategise these transitions](#). One example is the Battersea power plant in London, where the revamped site will soon supply renewable energy to a neighbourhood revitalised for people, flora, and fauna, using principles that support increased biodiversity. Sara Golingi, town planner from our Brisbane office, used this experience to consider options in the Australian context.



“The original research idea was to undertake a technical study of mine decommissioning, but it soon branched into a broader piece on community resilience and regenerative design.”

Sara Golingi

Mining change – from the future of mines to the future of communities

The team mapped existing thermal coal-fired power stations and mines across Australia and analysed their features. Creating a shortlist, they then selected three mine sites to take a deeper dive into regeneration options: Musswellbrook in New South Wales, Morwell in Victoria, and Jeebropilly in Queensland.

“To be honest, being a Queensland-based team, we were happy to see Jeebropilly make the shortlist,” Sara joked. Jeebropilly is located in South East Queensland (SEQ). Sitting adjacent to the Amberley Air Base and within 15 minutes’ drive of the Ipswich CBD, it also happens to fall within a Regional Economic Cluster. This gives it the potential to become a major economic hub within the [ShapingSEQ regional plan](#).

“To date, mine rehabilitation in sites like Jeebropilly has focused on revegetation, a low-hanging fruit for cattle grazing,” Sara says. “But the site as a whole has many local synergies and a huge range of other opportunities.” By looking at the bigger picture, the team saw great potential in redevelopment for purposes that align with both the regional plan and Ipswich City Council’s future vision for the city. Opportunities include defence, major enterprise, transport and logistics and advanced manufacturing including Industry 4.0 hubs.



Revegetation

Renaturation of a coal mine in Brandenburg, Germany.





Mining change – from the future of mines to the future of communities

By thinking at a strategic level, the team examined the entwined benefits for government, industry and community stakeholders. This process allowed them to identify specific strategies for site redevelopment, economy stimulus and a transition to clean energy. The potential benefits range from economic diversification to meeting emissions reduction targets to uplifting corporate social responsibility and improving employment prospects.

Through a distinct combination of technical knowledge, strategic mapping and community engagement, Sara and her team took rehabilitation beyond the ‘future of mines’ to the ‘future of communities’.

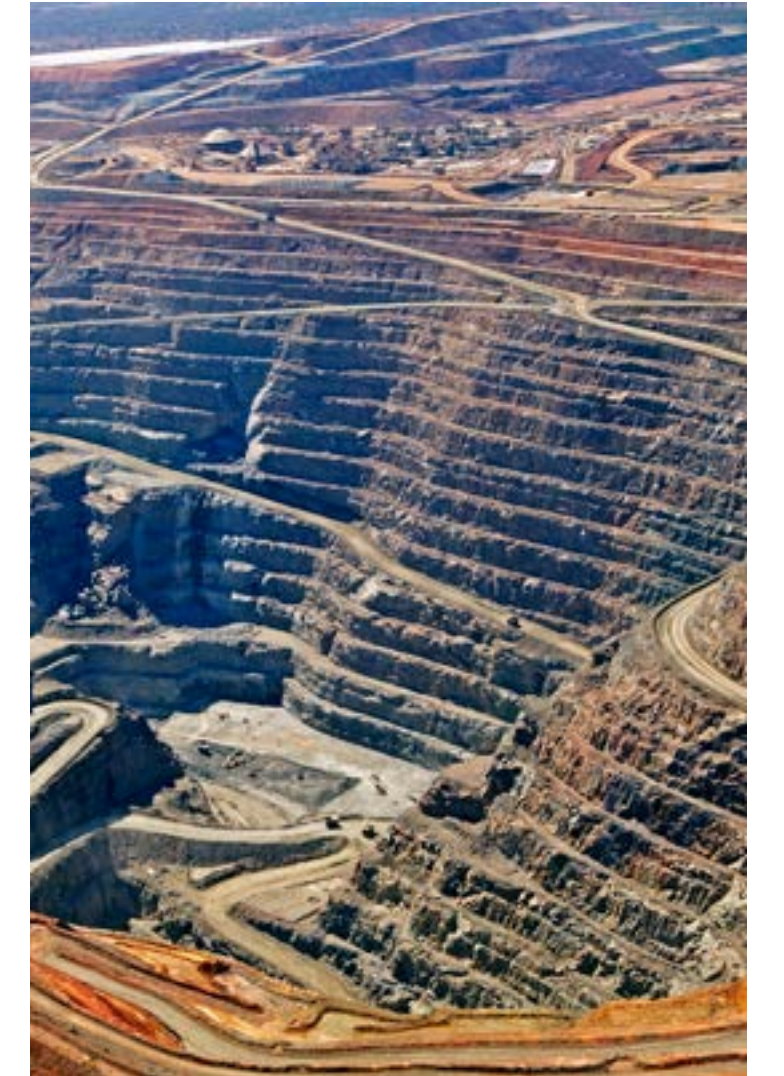
“We were engaged by the Torres Cape Indigenous Council Alliance to prepare an opportunity plan to advance the social and economic development of the Cape, Torres and Gulf region,” says Sara. Since parts of the region are heavily reliant on the mining industry, the plan explored opportunities for economic diversification and transition to new industries. The team also partnered with Arup’s community engagement program to drive social value, lead additional workshops, and better understand the opportunities and barriers to community growth.

The development of this opportunity plan, along with the work on mining rehabilitation and redevelopment, led to conversations with the Weipa Town Authority. This community, also built upon mining, showed an appetite for redeveloping sites to improve regional food production and, ultimately, food resilience.

“Arup has a strong point of difference here. With such a diverse range of skilled people, we can bring broad expertise to these multi-faceted projects, facilitating communication between stakeholders, providing strategy, design, development, maintenance and post-occupancy plans.”

Sara Golingi

To successfully achieve resilience when it comes to mines, a combination of expertise is required. Both engineering and community inclusion are vital. If we are to transition our energy systems efficiently and effectively to avoid catastrophic heating, now is the time for Australia to prepare. With a holistic and strategic approach, we can ensure a future that is renewable: both in terms of energy consumption and community health.



Supplying resilience – the future of Australian logistics

The Challenge

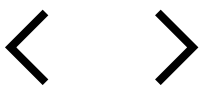
The movement of goods has seen a rapid change in recent years, where Covid-19 put a spotlight on the fragility of Australia's supply chain. Now is the time to ensure a more resilient and sustainable future for logistics as a fundamental part of our cities. Our team got together to look at the problem and to challenge the 'business-as-usual' status quo in favour of an outcome-led cities approach – how can logistics and our cities work better together?

Findings

- To make our current logistics industry resilient to shocks and stressors, we need to account for the interconnection of logistics with our cities, manufacturing, energy and the environment.
- An outcome-led approach can help the Australian logistics industry to achieve positive results for all those impacted - consumers, businesses, and environments across urban and regional areas.
- Arup's benefits-and-actions framework maps the interconnection of social, economic, cultural, environmental, and political benefits with a range of practical actions to rethink logistics beyond the simple movement of goods.

Billie-Grace Dunk

Engineer, Advisory Planning & Design,
Sydney office





Supplying resilience – the future of Australian logistics

Seeing supermarket shelves emptied of toilet paper was a shocking and disturbing sight for many Australians and a stark reminder that we live in unpredictable and fragile times. We've been exploring the implications of how supply chains are organised in view of Covid-19, climate change, a volatile political climate, and economic uncertainty. What does all this mean for an island nation like Australia, where freight and logistics generate an estimated annual revenue of \$103B? How can we help this industry to not only be more resilient to shocks like Covid-19 but an engine for positive change?

These questions inspired David Harding, NSW and ACT Business Leader, and Billie-Grace Dunk, an engineer and consultant in our Sydney office, to explore a range of possible solutions. The result: a regional multidisciplinary thought piece on The Future of Australian Logistics and our Cities.

“We looked at the current state of logistics in Australia and realised that we need numerous levels of resilience to balance our socio-economic needs with global markets and circular economy principles. The solutions have to be holistic, across-sectors, and engrained with sustainable mechanisms.”

Billie-Grace.



In a world of constant flux, it's a challenging proposition, and one that has to be considered globally. Before Covid-19 we were seeing a trend toward cities where people wanted the opportunity to work and play within 30 minutes of their front doors, creating two short daily travel peaks. The pandemic disrupted the '30-Minute City' to pivot us towards the '15-Minute Village', with roughly 40% of people now suggesting they wish to work from home 40% of the time.

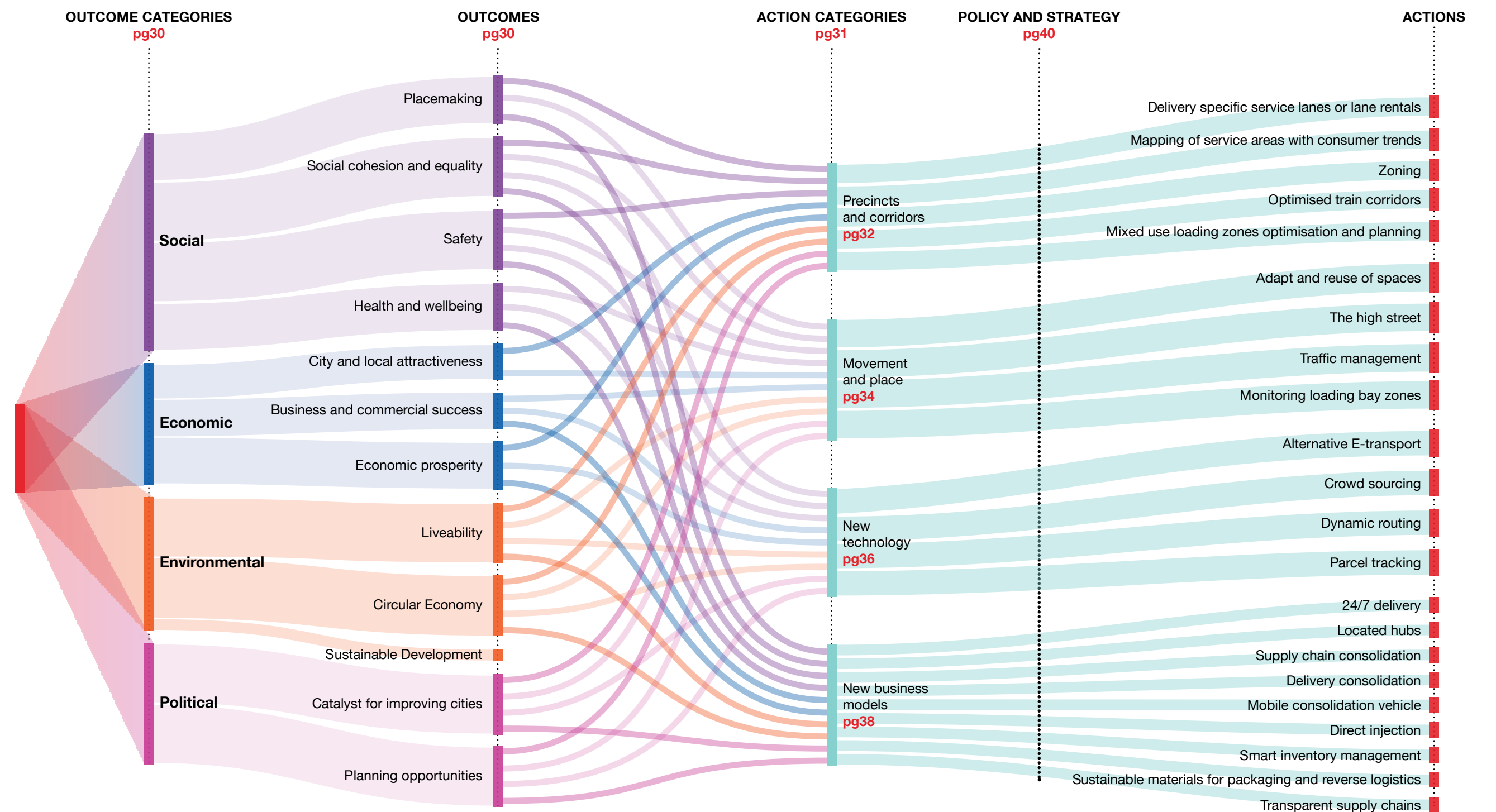


Supplying resilience – the future of Australian logistics

Similarly, even before Covid-19, e-commerce made huge changes to consumer patterns, bringing with its expectations of ‘always available products’ and ‘just-in-time’ services. When Covid-19 hit, the trend skyrocketed and could become a new normal. This has happened alongside a corresponding – and perhaps contradictory – growing awareness of environmental impact, bringing consumer demand for product provenance and greater supply-chain transparency.

To capture this ever-changing myriad of possibilities, the team developed a benefits-and-actions framework. “We workshoped ideas with key thought leaders across Arup,” says Billie-Grace. “Starting from laying out the desired wellbeing and socio-economic outcomes for our towns and cities, we worked backwards from there to identify key steps.”

What do we want to achieve for our cities?



How do we achieve these outcomes in our cities?



Supplying resilience – the future of Australian logistics

By examining the interconnection of manufacturing, logistics, energy and environmental aspects, the framework pinpoints ways to make effective and collaborative change between business, government, and consumer.

“People want more good delivered now than ever but they don’t want the vans on the road for noise, safety and environmental reasons. – so how can we help provide in a way that benefits everyone?,” adds Billie-Grace

For instance, the provision of critical health equipment like ventilators and masks achieves a range of benefits (social, economic, political). By making some practical interventions, like integrating platforms to monitor delivery service data, huge efficiencies can be made.

And, because no one-size-fits-all, having robust big data systems enables adaptive capability. When implemented, this could enable real-time logistics monitoring and enable adjustment to meet specific needs, and better monitoring of how effective a policy action is at town, city, or country level.

Even more positive scenarios emerge when strategy and technology embrace the United Nations Sustainable Development Goals. Shifting these gears may allow us to [re-frame resilience within the concept of business continuity](#)

for better resilience, and leverage regional and global economies. This may open the way to rethink how we target CO2 reduction goals, for instance by incentivising transport modes like zero emission vehicles.

These solutions offer a path to unlock social and economic benefits for our urban and regional areas. They reduce our carbon footprint and environmental impact. And, they enable our businesses to realise supply-chain transparency and provide a traceability layer to deliver more appealing services. “Environmental considerations are going to be a huge driver to change existing business models,” Billie-Grace notes.

Futureproofing Australian logistics is crucial to shaping a sustainable and resilient new normal. Whether it’s through mini distribution centres or more transparent supply chains, it’s time to think at a systems-scale to both withstand and absorb a diverse range of disruptions. Fortunately, the change is well within reach. By creating robust and holistic connections between the industry, our urban and regional areas, and the global markets, we can better ensure that the benefits reach consumers, businesses, local economies, and our wider communities.



Net Zero



The transition to a zero-carbon economy is accelerating globally. There is growing acceptance of the need to reduce our carbon emissions for our future and to avoid the worst climate impacts.

We look at the role of digital tools in the built environment and zero emission buses as approaches to significantly reduce carbon emissions.

In this section:

[Net-zero skyscrapers](#) ↗

[Driving the future](#) ↗

Concrete

One of the most carbon-intensive materials in the built environment



Net-zero skyscrapers: developing better high-rise buildings in South-East Asia

The Challenge

The built environment accounts for 39% of total global energy emissions. There is clear intent within the industry to radically improve this figure and meet net-zero by 2050.

Arup's Singapore office is prototyping a digital toolkit that calculates the carbon embodied within a high-rise building design. By forecasting emission costs up-front we can make better early design decisions.

Findings

- A carbon lifecycle assessment tool for construction materials can inform early design choices to reduce the carbon footprint of our buildings.
- Digital tools can correlate the embodied energy of a building with demographic lifecycle occupancy patterns, assisting the creation of generic but flexible high-rise residential design.
- We can accelerate circular economies by enabling location-specific, nimble responses toward material use, enabling a more resilient built environment.

Xavier Zhou

Senior Engineer, Buildings Group,
Singapore office





Net-zero skyscrapers: developing better high-rise buildings in South-East Asia

Cities with land-use constraints often turn to high-rise residential living to meet growing housing demands. This means more high-rise construction and, often, more demolition. Every building material has an embodied carbon footprint that reflects its supply chain history. Embodied carbon in construction materials will be responsible for almost 50% of total new construction emissions between now and 2050. How do we improve this figure?

Due to its urban density, Singapore is the perfect place to explore the role that digital tools can play in reducing construction emissions. Whilst the city generally has advanced green principles, residential high-rise buildings often get demolished as early as 25 years after construction (a shorter lifespan than many of the internal building systems). The research team focused on the early design stage of these new buildings as offering the greatest potential to make meaningful carbon change.

“The opportunities are huge,” says Xavier Zhou, an engineer from our Singapore buildings team and leader of the collaborative research project between Arup and the Singapore University of Technology and Design (SUTD), which was partly funded by the SUTD-MIT International Design Centre (IDC).



“In current industrial practice, nobody uses the carbon footprint as a criteria to compare design options at the early design stage, and we rarely consider how to extend building lifespan.”

Xavier Zhou

Net-zero skyscrapers: developing better high-rise buildings in South-East Asia

“We wanted to contribute to the creation of a lifecycle assessment toolkit to help the industry achieve excellence in the transition to a resilient design approach,” Xavier continues. The first part of the toolkit is a cloud-based parametric script that calculates the global warming potential of different construction and design options. Via a web-based interface, the user keys-in the building’s floor area, number of storeys, and basic proposed user demographic information. The tool generates a schematic building. The user then selects a unit and specifies a construction method and the materials for the various building elements (i.e. a concrete beam, a steel frame, a glass window).

Within minutes, the script calculates the background lifecycle carbon footprint of the ‘shoebox’ unit which, when multiplied, reflects the performance of the entire building. Designers can use this global warming potential to swiftly quantify and compare the lifecycle carbon footprint of different construction, material, and design options. Achieving even a slight saving on the embedded carbon within a single unit can dramatically improve overall building resilience and – when applied across multiple buildings – whole city resilience.

This first part of the toolkit has laid the groundwork for the second, more holistic, part of the research. “We were interested in the embodied energy of a building and its correlation with accommodating demographic changes over its lifetime,” says Prof Michael Budig, Principal Investigator of the project at SUTD. “With a user-driven parcellation approach, a flexible building does not have to be fully occupied all the time. Parts can remain empty and become shared spaces that serve a more vibrant residential community.”



Net-zero skyscrapers: developing better high-rise buildings in South-East Asia

To achieve more resilient design alternatives, the team focused on how to accommodate functional changes in high-rise residential buildings. Using open polyvalent floor plans, they studied hybrid concrete-timber construction options.

“For example, this ‘resilience quantification’ allows us to predict that whilst the current bulk demand is for 5 room units that, due to the ageing trend and smaller nuclear families, in 20 years the bulk demand will likely be for 2 room units. So, our original intent at the design stage is to ensure flexibility in the longer run.” – Prof Budig



Using digital tools to achieve more holistic approaches to design and construction can be applied beyond residential building projects. Large scale infrastructure projects, such as roads and train stations, are often more carbon-intensive than high-rise buildings. Originally developed in the London office, the Arup carbon tool was used by our infrastructure team in Copenhagen to show that a shallow underground metro station would create about 50% less embodied carbon than the deeper

station design of existing metro lines. The tool is now being adopted and adapted globally. In Australia, it’s being tailored to local open-source libraries like the [EPiC database](#) so that the local and global supply chains of a range of materials can be modelled transparently.

“Tools like this are influencers to reduce the industry’s carbon footprint; in the long term, they will completely change the way we approach the full lifecycle of materials - from design phase to reuse.”

Xavier Zhou

Making supply chains transparent through digital tools also helps to create circular economies. In South Africa, our [DigiYard](#) app is being used to tackle the other end of the spectrum – reuse of materials. Currently in development, the app aims to link surplus and waste building materials with people living in informal settlements using a circular economy framework.

“The idea is that the app quantifies the materials, identifies their location, and makes the information available to consumers. The materials can then be transported efficiently and economically by linking into existing networks,” explains Jaco Kemp, co-creator of the app and Digital Transformation Specialist.

It won’t be long before digital tools like DigiYard and the carbon lifecycle assessment toolkit mature and realising their potential to help us reach net-zero cities. Along the way, they will also help us achieve circular economies and create new business opportunities.



Driving the future: zero emissions buses

The Challenge

We did the introductory and concluding research around the inaugural Zero Emissions Bus (ZEB) forum with government and industry focusing on transforming our bus system to net-zero. Charting the issues and opportunities of electric buses, hydrogen buses, charging systems, bus operations, ownership structures and more, we laid the foundations for a new nation-building project.

Findings

- Transitioning to ZEBs presents significant nation-building opportunities.
- Much of the technology is already tried and tested.
- ZEBs can bring benefits all-round, including for passengers, bus operators, maintenance crew and drivers, as well as for pedestrians and cyclists.
- Policy certainty, collaboration and sharing between stakeholders is vital to optimising infrastructure investments and accelerating the achievement of climate goals.

Joey Schaasberg

Senior planner, Advisory Planning & Design,
Sydney office





Driving the future: zero emissions buses

The longer we take to reduce our carbon emissions, the more we'll be affected by global warming. So how do we reach net-zero quickly? One key is to focus on the right sectors with existing, proven technologies. Transport is one of the largest greenhouse gas emitters in Australia, and offers huge opportunities for decarbonisation in Australia and New Zealand.

“In Shenzhen, 18 thousand buses were converted to zero emissions between 2013-2018,” says Joey Schaasberg, a Senior Transport Planner based in our Sydney Office. “The technology is mature. It's the transition that needs work.”

To help drive things along, we partnered with Transport NSW and the International Association of Public Transport (UITP) to run the inaugural Zero Emissions Bus (ZEB) forum. Pre-informed by an in-depth [discussion paper](#), three hundred people from government and industry attended. With 9 sessions over 6 weeks, discussions covered the vast range of associated factors, including: policy, planning, transition, technology, ownership and operations.

“What's really exciting is that a coordinated, systems-led approach could deliver zero emissions for Australia and New Zealand by 2035,” says Mark Rowland, Director – Integrated Network Planning and Programs at Transport for NSW.

“And with a smart process that accounts for cradle-to-grave emissions, we could unlock economic benefits and next-generation jobs.”

Entirely new markets could be created from design and manufacturing, through to battery maintenance and energy resilience. As ZEBs are modular, we could build micro manufacturing plants in each of our cities, filling the gap left by automotive. And this know-how could then be transferred to other fleets like waste trucks and smaller passenger vehicles.



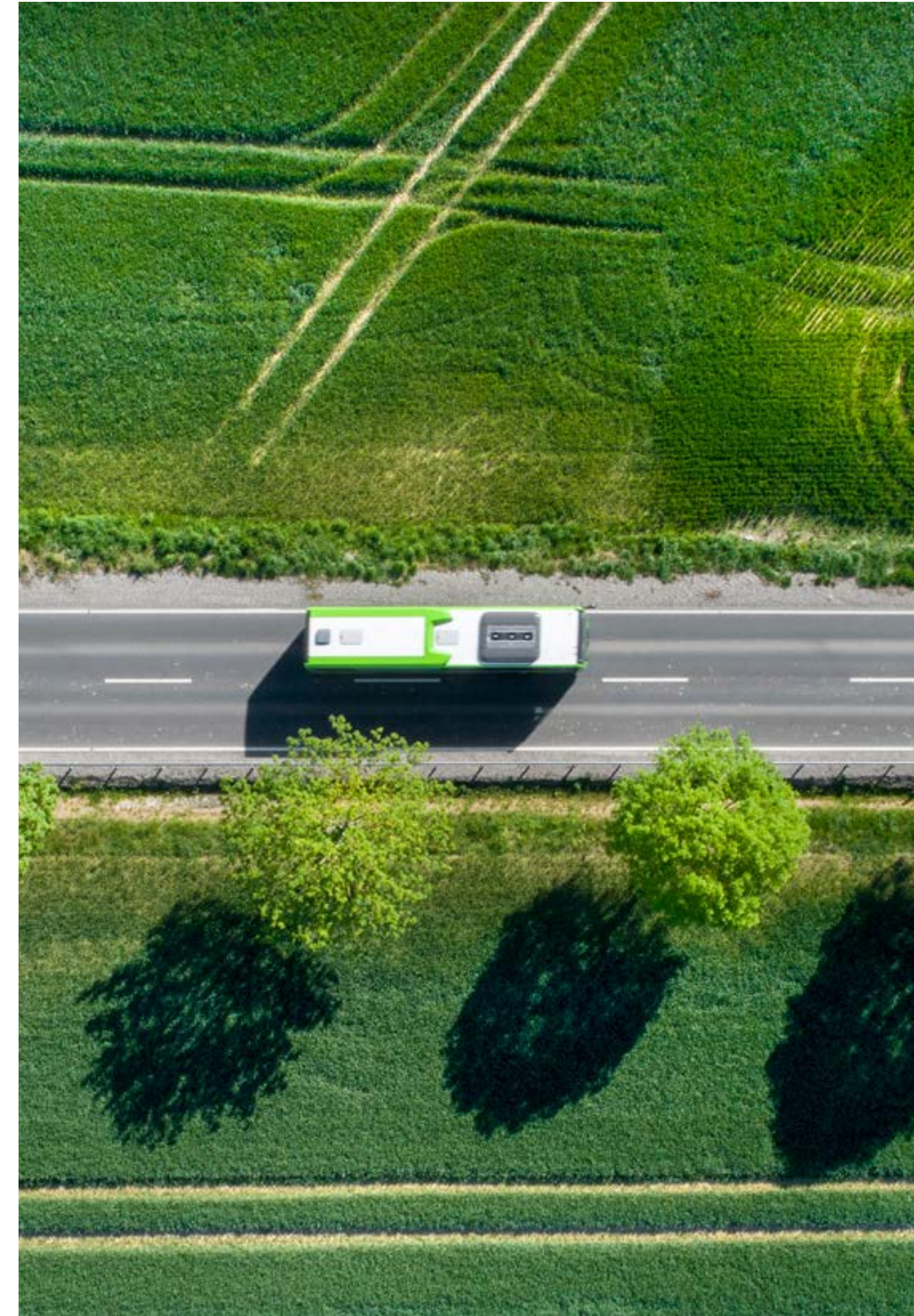
Driving the future: zero emissions buses

“In Australia, we also have the ability to develop advanced manufacturing and next-generation jobs. We already manufacture a lot of buses here.”

Joey Schaasberg

What makes the opportunity even more attractive is that most of the technology has already been tested. The UK, EU and China have started decarbonising bus fleets by setting aggressive national targets. Whilst it's governments often pushing the agenda in these countries, Australia and New Zealand have seen strong industry-led initiatives, such as Volvo [leading electric bus trials](#) in Western Australia.

The forum also raised ideas for new social benefits that may redefine the 'bus' customer experience – from lower noise and pollution through to a smoother ride. What we are witnessing is a rare moment to reimagine our roads and streets where vehicle sizes are customised to match service requirements.





Driving the future: zero emissions buses

But there are, of course, multiple complexities. There's concern that acting on 'hype' could cut-off other approaches. For example, one person asked: "If the objective is to reduce CO2 emissions, wouldn't we be better to get more people out of private cars and onto low emission diesel buses? We need to remain agnostic and consider what is the appropriate response(s) to achieving the desired policy outcome." To this, another person responded: "It could become hard to justify the green credentials of an old diesel bus if someone can just as easily drive around in a modern electric car powered by renewable energy."

Mark notes, "There is still a role to play in education about the existing technology. Many people don't realise that most ZEBs can do 400km a day. That distance covers 85% of Sydney's routes. And battery technology continues to improve. A ZEB may cost more upfront, but it's soon recouped when you consider whole-of-life costs where ZEBs are cheaper to run and demand less maintenance, let alone the environmental and social benefits like reduced noise and pollution."

Since the discussion paper was released, [significant concrete action has been announced by many jurisdictions](#). New South Wales is converting its fleet of 8,000 buses to ZEBs by 2030. Queensland is transitioning to ZEBs by 2030. South Australia is transitioning to low or zero emissions vehicles over the next 10-15 years. Victoria is commencing a \$20m trial. Auckland Transport is targeting a full ZEB fleet by 2040, with all buses

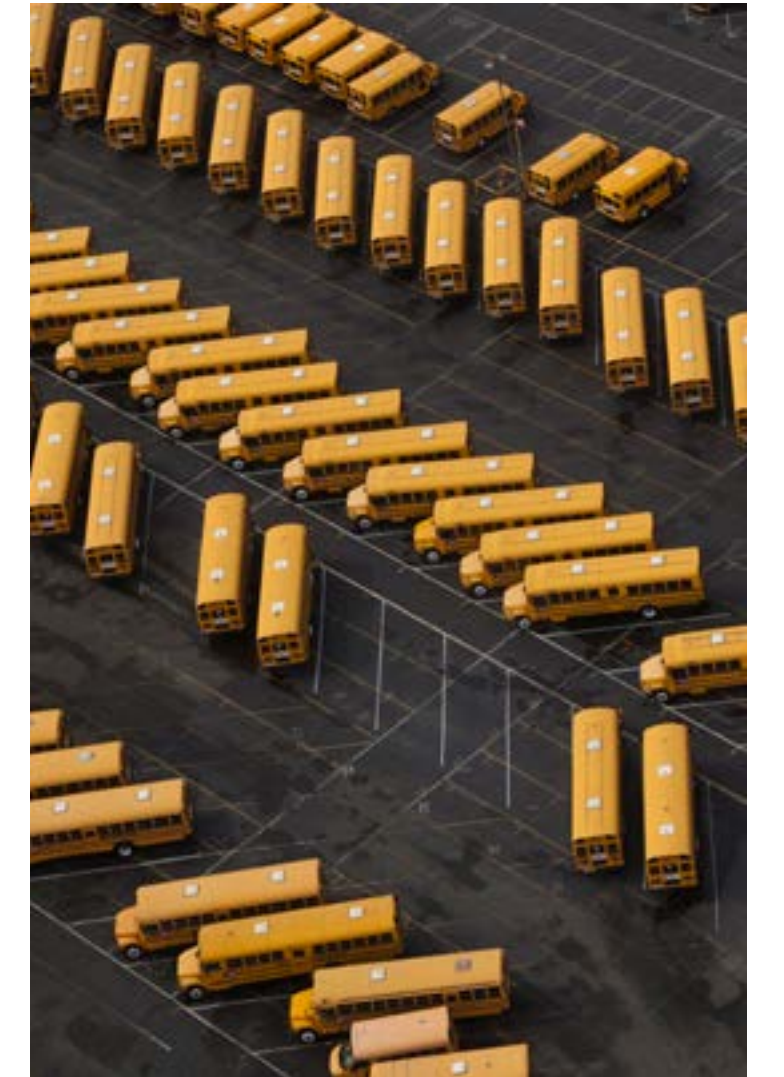
to be procured as zero-emission vehicles from 2025. And Wellington is leading the charge, expecting to have around 110 ZEBs on the road (25% of the fleet) by mid-2023 and 100% by 2035.

To ensure coordinated development of targets and standards (let's not repeat the [inefficient rail gauge situation](#)), we need jurisdictions to share information and learnings. "I'd really like to see a point of coordination across the jurisdictions," says Joey. By enabling certainty we are more likely to achieve system interoperability, building users' trust and supporting system resilience.

Adopting a zero-emission bus ecosystem nation-wide requires strategy, coordination, and investment. The transition to ZEBs would not only reduce emissions, it could be a nation-building exercise under Infrastructure Australia's nationally significant investment priority. Our actions must be system-wide, stimulating jobs, manufacturing and the economy.

Through this lens, decarbonisation and sustainable development go hand in hand. Asking the right questions now, will get us to the right answers later.

Let's drive into the future with a clear destination.



Meet the team



Research at Arup is a collaborative effort. We create cross-disciplinary, cross-regional teams from the 14,000 people who work at Arup globally, and pair them with our partner organisations.

Over 470 Arupians worked directly on research projects in the Australasia region alone between 2020 and 2021.

**Bree Trevena**

Australasia Research Leader, Arup
Foresight, Research + Innovation

Bree directs our research program. She has a background in policy and strategy with a focus on precinct planning and public cultures.

**Alessandro Liuti**

Research Manager, Arup Foresight, Research + Innovation

Alessandro manages our research program. He has a background in architectural engineering, computational design, and digital fabrication

**Siobhan Hudson**

Research Coordinator, Arup Foresight, Research + Innovation

Siobhan coordinates our research skills and sharing program, as well as research value capture. She has a background in urban planning, data visualisation and social value.

Among the contributors of this Arup Research Review:

[Eleanor Whitworth](#), and [Noel Smyth](#)