



**GETTING THE MOST
OUT OF THIS PDF**

The 2018 report uses multiple page sizes to communicate the rich mix of projects and people we have been involved with this year. In this PDF, these pages are indicated by a small page fold in the bottom corner.



**MOUNT FUJI WORLD
HERITAGE CENTRE**

Honshu, Japan

The building's funnel-shape form takes inspiration from the volcano beyond.



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As a firm, we have never been satisfied with standing still and relying only on the tried and tested. Instead, we relentlessly pursue new ways of working, digital breakthroughs, and pioneering collaborations that expand the positive impact we make for our clients, our partners, and the world we all live in. This report looks back at another year of going above and beyond...

THE YEAR IN BRIEF

6,500

Clients served

13,840

Average number of
staff members

146

Countries where
we have worked

FORWARD ORDER BOOK (£BN)

2016	1.04
2017	1.05
2018	1.31

REVENUE (£BN)

2016	1.24
2017	1.51
2018	1.56



CHAIRMAN'S STATEMENT

Gregory Hodkinson

As a firm, we aim to shape a better world. This drives everyone at Arup to find new ways to make it a practical reality, and not merely a worthy aspiration.

I am pleased to report good progress on this front over the past year. We can always go further and do more, but across the firm there is clear evidence of our determination to expand the positive impact we make – for our clients and for society as a whole. It is this determination that makes our work distinctive, and continues to bind us together as an organisation.

In the first quarter we launched our refreshed Group strategy to the firm, which explicitly responds to a changing world. Drivers, including population growth, urbanisation, globalisation, climate change, resource scarcity and digital transformation, present us with new challenges and opportunities.

As an independent firm that combines deep technical knowledge with sharp strategic thinking and a creative mindset, we are well placed to address these issues.

Our strategy considers these developments through the lens of our four main markets: cities, energy, transport and water. We have specific objectives in each area that balance opportunity with a clear sense of responsibility, but it is also evident

that these markets are increasingly converging, which means our services and solutions are increasingly converging too. Our multidimensional work on major development projects like *Madrid Nuevo Norte* (see page 38) shows what benefits this brings in practice.

Our strategic approach is collaborative to the core, enabling us to mobilise multidisciplinary teams to support the most complex programmes. This breadth of expertise and creativity means we can help government clients on vital national infrastructure projects. Last year, we were awarded major commissions on the United Kingdom's *High Speed 2 Rail Programme*, demonstrating how our firm continues to contribute to critical public schemes.



▲
HIGH SPEED 2
United Kingdom

One area where the convergence across markets is apparent is in our Advisory Services. Clients across the world are increasingly recognising the value we bring by combining our technical expertise in the built environment with relevant skills across strategy, economics, financing, programme management and operations. Projects like *Endeavour Energy* in Australia (page 51) and the *Delta Airlines Terminal Modernisation Programme at LAX* (page 94) are examples of work that allows us to expand our client impact.

GLOBAL REACH

Our refreshed Group strategy identified certain regions of the world in which we see opportunities to develop our practice, to better meet the challenges of shaping a better world.

Our work in China and with outbound Chinese clients has continued to flourish. Building on relationships stretching back over 40 years, we are helping the country continue its remarkable evolution. The pace, scale, and quality of innovation involved is often breathtaking, emblematic of the ambition we are responding to.

Clients in China have shown increasing interest in our sustainable development expertise, as evidenced by our recent memoranda of understanding with China's Smart City Development Alliance. These will see us leading smart city development, embedding sustainable best practice across the country, and undertaking research into the application of circular economics,

urban innovation, and green design. We expect much of our work in China and across the world to be shaped by this kind of thinking in the years to come.

We are conscious that we are living in what is often described as the 'Asian Century'. With this in mind, we are making sure we have effective resources in the countries where development is dynamic and demand for our services is strong. Across Southeast Asia, we now have 10 permanent offices and 1,000 staff members. This year we have strengthened our presence in Malaysia and Indonesia, and are coordinating our development in a region that is expected to become the fourth largest economy in the world by 2030. Projects like the major upgrade to *Drinking Water Supply* in Hanoi (page 59) are typical of the positive effect our work is having.

Our operations in North America have continued to prosper, with strong demand for our services. Our mix of work in the region is evolving towards ever higher value services, and we are continuing to establish a strong presence beyond our hubs on the East and West coasts of the US. Canada is also a growth market and our work on the new *Champlain Bridge* in Montreal (page 95) and the *Toronto Subway* (page 92) are good examples of our expansion there.

▶
VAUGHAN METROPOLITAN CENTRE STATION
Toronto, Canada

COMBINING TECHNOLOGY AND DOMAIN EXPERTISE

Another strand of development this year has been a concerted focus on digital transformation.

We have always been a firm that is eager to embrace new technology, with iconic projects like the Sydney Opera House utilising the most advanced computers of their day. It is clear that we are now entering a period where the impact of digital technology will increase exponentially. This has been driven by a rapid rise in computing power, richer and more widely available data, and fast emerging advances in machine learning and artificial intelligence.

We have made significant progress in five important areas: automation, data, digital services, digital products and technology. Our colleague Fiona Cousins further explains our thinking around digital transformation on page 10. Projects like our work on *3D Printing in Steel and Concrete* (page 15) and *Driverless Cars* (page 17) demonstrate the impact we are already making.



SHAPING A SUSTAINABLE FUTURE

As with technology, a commitment to sustainable development is a long-established part of our culture, stretching back to Ove Arup's aims for the firm to be 'socially useful' and a 'humane organisation'.

Across the world there has been a growing realisation that concerted and substantial steps are required if we are to create a future where people and the planet can both thrive. The United Nations Sustainable Development Goals (SDGs) represent a pathway to achieving the changes required. Over the past year, we have put plans in place to align our work with the SDGs. Peter Bailey and Jo da Silva have been leading that work and Jo's views on why and how we are embedding the SDGs can be found on page 34. Our work helping cities like New York to develop comprehensive *Climate Action Plans* (page 37) demonstrates how our deep expertise in this area is already being put into action.

A MEMBERSHIP OF QUALITY

Ove Arup spoke about an organisation that is "always human, always living, always learning, always changing." These principles remain highly relevant today and shape much of what we do to broadly support the development of our colleagues across the firm and specifically through the work of Arup University.

This work goes beyond the confines of professional development and offers insights developed with external thought-leaders, firm-wide skills networks, and cutting-edge collaborative and research tools.

A subject worthy of a particular focus is the diversity of our membership where we seek to facilitate better performance and outcomes. As we work in a sector that has traditionally been male dominated, an obvious area of focus is gender balance. We are determined to reach a point where our membership is balanced between the genders and also more diverse in all respects. We have taken specific steps around gender balance this year (see page 25) and there is more work to do. Our Board is determined to ensure that we maintain the momentum around diversity, equality and inclusion in the years ahead.

SELECTED AWARDS

This year's selected awards confirm our commitment to quality and our desire to push new boundaries. As always they are a testament to the strength of our partnerships with clients and collaborators, and to the expertise and commitment of our talented people.

AUSTRALIA

200 George Street *Sydney, Australia*

- Australian Institute of Architects, The Harry Seidler Award for Commercial Architecture
- Council on Tall Buildings and Urban Habitat, Best Tall Building Award

Anna Meares Velodrome

Chandler, Australia

- Consult Australia Awards for Excellence, Gold Award of Merit – Design Innovation

Australian Centre for Corporate Social Responsibility

Top ten firms for Corporate Social Responsibility

Engineers Australia

- National Gender Diversity Awards, Most Outstanding Company in Gender Diversity

Macquarie University Innovation Hub

North Ryde, Australia

- Australian Timber Design Awards, Innovative Structural Design Award

The Australian Top 100

Graduate Employers

Construction and Property Services sector

CANADA

National Music Centre of Canada

Calgary, Canada

- American Council of Engineering Companies, Platinum Award, Building/Technology Systems



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sharing

of me not to address including Brexit. nificant revenue from s, we are mindful of o-economic effects anges, including ct the highly skilled e to need. We will riate to developments

clear that the world redictable, shaped tical, social and It is also true that oration to address es is greater than , as our alignment ations Sustainable ls shows, we are art as a firm, and ted, committed e. It is this sense purpose from our s me most hope for s through in every It reflects a deep o make 'we shape a y than a catchphrase mpact we make

SELECTED AWARDS

SHAPING A SUSTAINABLE
FUTURE

As with technology, a focus on sustainable development is a long-established part of our DNA, stretching back to Overton for the firm to be 'social and a 'humane organisation'.

Across the world there is a growing realisation that taking and substantial steps are needed if we are to create a future for people and the planet. The United Nations Sustainable Development Goals (SDGs) are a pathway to achieving the changes required. Over the past year we have put plans in place to align our work with the SDGs. Peter da Silva and Jo's views on why this is important and embedding the SDGs into our work are on page 34. Our work in cities like New York through our comprehensive *Climate Resilience Plans* (page 37) demonstrate our deep expertise in this area already being put into practice.

GREATER CHINA

Midfield Development, Hong Kong International Airport

Hong Kong
– Hong Kong Institution of Engineers, Structural Excellence Award – Infrastructure

National Taichung Theater

Taichung City, Taiwan
– Institution of Structural Engineers, Structural Awards – Award for Construction Integration

Shatin to Central Link Tunnel

Hong Kong
– International Tunnelling Awards, Project of the Year

Yujiapu Traffic Hub

Tianjin, China
– China Steel Construction Society, Award of Science and Technology
– Hong Kong Institution of Engineers, Structural Excellence Awards – Mainland/Overseas Category

GREECE

Stavros Niarchos Foundation Cultural Center

Athens, Greece
– Royal Institute of British Architects, Award for International Excellence

JAPAN

Naoshima Hall

Naoshima, Japan
– Architectural Institute of Japan, Architectural Design Division
– Wallpaper Design Awards, Best New Public Building

KENYA

Kericho Cathedral

Kericho, Kenya
– Lighting Design Awards, Daylight Project of the Year
– Surface Design Awards, Light and Interior Surface

MEXICO

Torre Reforma

Mexico City, Mexico
– National Council of Structural Engineers Associations, Excellence in Engineering Awards – New Buildings

NETHERLANDS

Museum Voorlinden, Caldic Collection

Wassenaar, Netherlands
– Royal Institute of British Architects, Award for International Excellence

People's Pavilion

Eindhoven, Netherlands
– Frame Awards: Societal Awards – Sustainability – Jury Prize

POLAND

National Forum of Music

Wroclaw, Poland
– United States American Council of Engineering Companies, Platinum Award for Engineering Excellence – Building/Technology Systems

SINGAPORE

Singapore Sports Hub

Kallang, Singapore
– ASEAN Federation of Engineering Organisations, Outstanding Achievement Award
– Singapore Institution of Engineers, Prestigious Engineering Achievement Award

SPAIN

Barcelona-El Prat Airport Area Development

Barcelona, Spain
– European Council of Spatial Planners, European Urban and Regional Planning Awards – Airports, Cities and Urban Development

SOUTH AFRICA

V&A Grain Silo Complex

Cape Town, South Africa
– Concrete Society of Southern Africa, Fulton Award – Innovation in Concrete
– Council on Tall Buildings and Urban Habitat, Best Tall Building Award – Middle East and Africa

UNITED KINGDOM

Design Museum and Holland Green

London, England
– Institution of Structural Engineers, Structural Awards, Award for Structural Transformation

Forth Replacement Crossing

Firth of Forth, Scotland
– Association Québécoise des Transports, Prix Ambassadeur
– Ground Engineering Awards, Project of the Decade
– Scottish Transport Awards, Outstanding Project in a Generation

UNITED STATES OF AMERICA

2nd Avenue Subway

New York, United States
– United States American Council of Engineering Companies, Diamond Award for Engineering Excellence – Transportation
– United States American Society of Civil Engineers, Outstanding Civil Engineering Achievement Award

Bar Association of San Francisco

Justice Diversity Center
Crystal Award for Community Service Given to Arup for our work on Homeless Advocacy

Broad Art Foundation Museum

Los Angeles, United States
– Surface Design Awards, Supreme Winner

Northeastern University Interdisciplinary Science and Engineering Complex

Boston, United States
– American Council of Engineering Companies, Gold Award of Engineering Excellence



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sharing

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CHAIRMAN'S STATEMENT

SHAPING A SUSTAINABLE FUTURE

As with technology, a focus on sustainable development is a long-established part of our DNA, stretching back to Overton. For the firm to be 'socially responsible' and a 'humane organisation'...

Across the world there is a growing realisation that taking meaningful and substantial steps to address the challenges we are to create a future for our people and the planet. The United Nations Sustainable Development Goals (SDGs) provide a pathway to achieving these objectives. Over the past year, we have put plans in place to align our work with the SDGs. Peter da Silva and Jo's views on why embedding the SDGs into our work is on page 34. Our work in cities like New York through our comprehensive Climate Plans (page 37) demonstrate our deep expertise in this area already being put into practice.



GUIDED BY EXPERIENCE

Our strategy is set by the Group Board, appointed by the firm's Trustees. The Group Board is responsible for Arup's long-term success, financial security, unity, well-being, and sustainability.



GROUP BOARD

- | | |
|--|--|
| Gregory Hodkinson ¹
<i>Chairman</i> | Jerome Frost ⁷ |
| Alan Belfield ²
<i>Deputy Chairman & COO</i> | Michael Kwok ⁸ |
| Tristram Carfrae ³
<i>Deputy Chairman</i> | Dervilla Mitchell ⁹ |
| Peter Bailey ⁴ | Matthew Tweedie ¹⁰ |
| Peter Chamley ⁵ | Fergal Whyte ¹¹ |
| Fiona Cousins ⁶ | Genevieve Shore ¹²
<i>Non-Executive Director</i> |
| | Tim Stone ¹³
<i>Non-Executive Director</i> |

OFFICERS OF THE BOARD

- Martin Ansley-Young¹⁴
- Karim Klaus Emara¹⁵
- Clare B Marshall¹⁶
- Rob Greig¹⁷
- Paul Robinson retired from Arup at the end of March 2018.

£1.56bn

Total revenue for the year

12.2%

Operating profit margin before staff profit sharing

REASONABLE PROSPERITY OF MEMBERS

I am pleased to report that we have again achieved a reasonable financial performance that is well aligned to our strategic objectives. Our revenue grew to £1.56bn, an increase of 3.6%. Our operating profit margin, before staff profit-sharing, was 12.2%. Our forward order book is robust, a clear measure of the faith and support our clients continue to place in us.

RISKS AND RISK MITIGATION

In recent years our industry, and our professions within it have seen a shift in risk allocation to a position that is far from ideal. As an independent trust-owned firm we are under no external pressure to take undue risk in pursuit of profit, yet we remain vigilant and continue to carefully manage threats to our strength and stability, including avoiding assignments where we consider the allocation of risk to be unacceptable.

It would be remiss of me not to address geopolitical risk including Brexit. As a firm with significant revenue from our UK operations, we are mindful of the potential macro-economic effects of major policy changes, including our ability to attract the highly skilled people we continue to need. We will respond as appropriate to developments as they unfold.

More broadly, it is clear that the world is becoming less predictable, shaped by a changing political, social and economic climate. It is also true that the need for collaboration to address critical global issues is greater than ever. On that front, as our alignment with the United Nations Sustainable Development Goals shows, we are eager to play our part as a firm, and as a group of talented, committed professional people. It is this sense of enthusiasm and purpose from our members that gives me most hope for the future. It shines through in every Arup office I visit. It reflects a deep and shared desire to make 'we shape a better world' more than a catchphrase as we expand the impact we make across the globe.

GREGORY HODKINSON
Chairman



DIGITAL & INNOVATION

Advanced technology has long been a notable feature of our work – right back to our pioneering use of computers on the design of the Sydney Opera House. However, in recent years there has been a dramatic shift in technology’s relationship with business, comparable to the Industrial Revolution in terms of its scale, speed and impact.

FIONA COUSINS

Location
New York

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s big data to improve their
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TO ACTION

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RESPONDING TO THE AGE OF DATA

With data richer and computing power cheaper than ever before, we asked ourselves two searching questions: how can we take our technology-driven mindset and go even further? And how can we keep pace with a world that keeps developing at an ever-greater rate? We decided to concentrate our response in four areas: automation, data, products, and services.

AUTOMATION AND DATA

Automation is all about improving the quality and speed of our analysis. For example, making and understanding changes to utilities networks over multiple design iterations across a masterplan has always been a laborious task – until now. We have found new ways to automate much of the process, allowing for the continual optimisation of the engineering. We are now making similar advances across all our operations, focusing on reducing the duplication of our thinking and our work.

Shifting mindsets is a big part of this. While every project is unique, if we are facing a challenge in one location, the chances are someone in our network has a tool or methodology that can help us solve it. We just need to use the new systems available to us, and be more open about sharing and collaborating. We've put a lot of processes in place this year to ensure this happens.

The second focus area sees us taking a data-driven approach to everything we do. With the rise of the 'Internet of Things', data is increasingly abundant and can lead to better results based on a greater depth of 'in use' evidence. Take our lighting team. Glare has always been something that's difficult to predict. However, using data analysis and machine learning, the team has improved glare predictability from 70% to 90% – a substantial improvement.

PRODUCTS AND SERVICES

Our third priority is the digital products we can offer our clients. We used to build software mainly for internal use – now we are starting to create tools our clients can use themselves. Our *SNAPshot Tool* is a prime example. Developed by our acoustic consultants, it enables clients to carry out tailored noise modelling and assessments on their projects, allowing them to rapidly undertake 'what if' scenarios, improve their decision making, and fast-track approvals.

Finally, we are focusing on our digital advisory services. Many of our clients are also adapting to this increasingly connected world. Recently, we have been working with major airports like *Dubai International* (page 12) to help them harness big data to improve their operations and reduce risk. There is similar scope across all our markets.

STRATEGY TO ACTION

We have made great strides this year in all things digital. Putting the Digital Council in place was an important step as it allowed us to coordinate and report on everything we are doing across our operations.

We also shared our digital vision with the whole firm and set up a series of 'conversations' to outline what we expect from our staff members. This is helping move us from strategy to action – ensuring everyone recognises the digital opportunities available and makes them part of their daily activity.

Finally, it's important to note that amidst this digital revolution, our business will fundamentally remain the same. It will always be about providing deep technical expertise and innovative solutions to the toughest challenges our clients can throw at us. Digital simply allows us to do that better and faster – producing results that otherwise wouldn't be possible.

**EXPANDING CAPACITY
THE SMART WAY**

Airports are an area where smart application of digital technology is providing immediate benefits.

At London’s *Heathrow*, we have digitally mapped the airport’s entire baggage handling process in one model – improving efficiency, increasing capacity and offering a better service to 78 million passengers a year. You can read more about this work on page 86.

In the Netherlands, we are helping *Schiphol Airport*’s operators put digital technology at the heart of major expansion plans. As Systems Integrator, our role is to ensure that the myriad of systems underpinning the new pier and terminal work seamlessly and in unison with the existing facilities. Covering everything from IT, data communications, and life-safety to security, check-in, boarding and border control, this complex task is vital to the ultimate goal of increasing capacity by 14 million to over 70 million passengers each year.

Managing IT complexity is also a feature of our work at *Dubai International*, the world’s busiest airport.

Our digital efficiency initiative, ‘Real Time Airport’, gathers, analyses, and shares data from all the airport’s IT systems in real time. This allows staff in any part of the airport to see what’s happening elsewhere, enabling them to react and respond to passenger needs before problems arise. Without building any new facilities, the airport has managed to cut average queuing times in half despite passenger numbers increasing by up to 10% a year.

**APPLYING DIGITAL
AT SCALE**

Across the world, businesses, organisations, and even whole cities are looking to maximise the opportunities digital technology provides. In Sydney, Arup partnered with the city to develop a strategy outlining an inclusive and mature approach to using digital technology to deliver the outcomes of the *Sustainable Sydney 2030* plan.

The strategy is fundamental to maintaining Sydney as a globally competitive city with equitable opportunities and benefits for all residents, businesses, and visitors. It is also people-first, both in its focus on community and the organisational change necessary to transform.

Through dialogue and participation, Arup helped convince key stakeholders that digital transformation must cut across all aspects of metropolitan governance – and that the role of government has the potential to evolve in today’s digital age. The Arup team provided knowledge and experience in digital technology, urban planning and strategy development throughout the project, supported at regular intervals by our global specialists in smart city development.

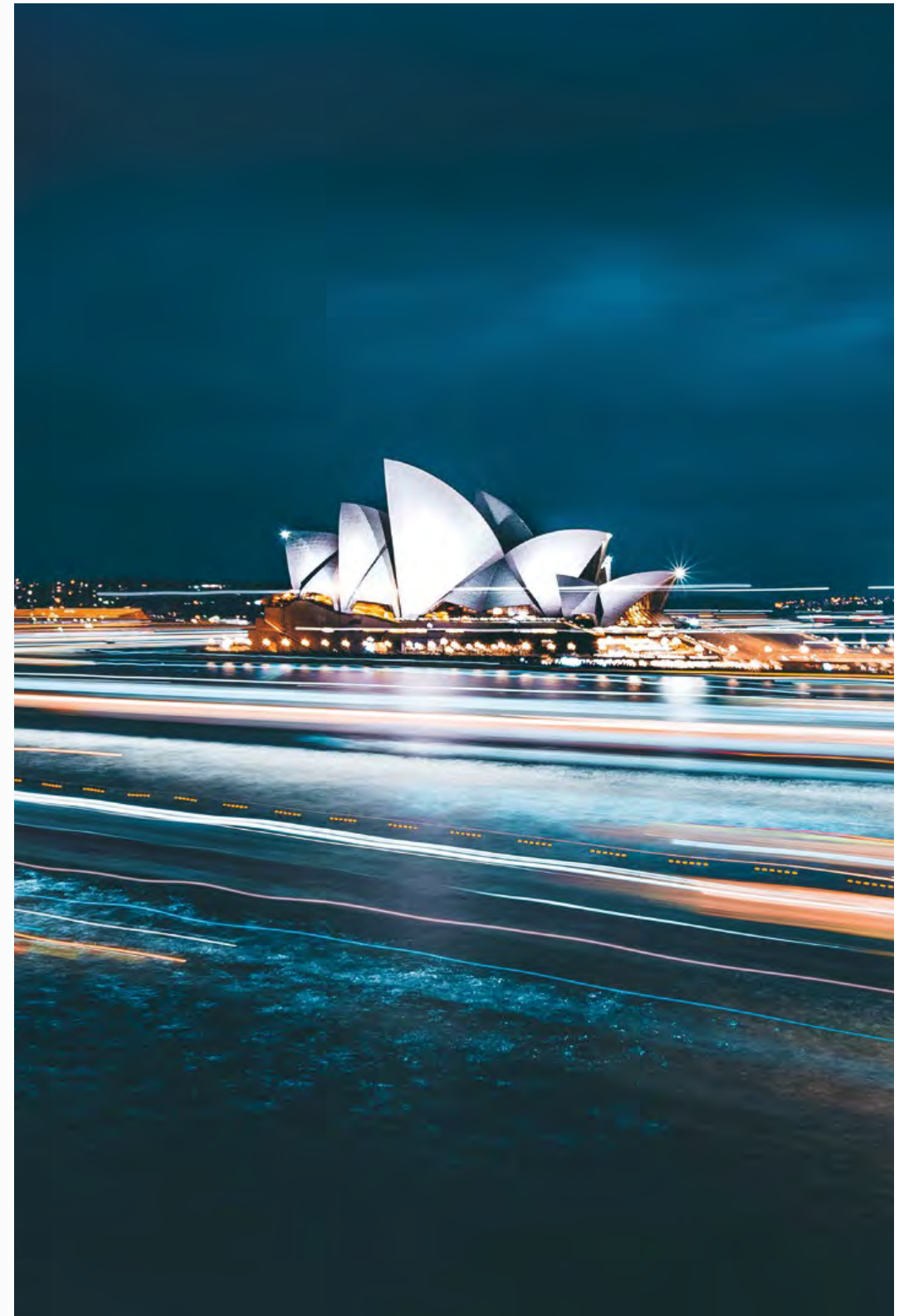
At the conclusion of the strategic development process, the city had a clear understanding of the digital activities needed to deliver its Sustainable Sydney 2030 strategy. Endorsed by the council in 2017, it remains the guiding policy for current implementation efforts.

2030

Our work with Sydney on a new digital strategy will help the city deliver commitments within the Sustainable Sydney 2030 plan

▶ **SHAPING OUR CITY**
Sydney, Australia

As part of a series of *Shaping our City Forums* in Australasia, the Sydney forum explored how data and technology can be harnessed to create a more liveable, efficient and greener Sydney.





3D-PRINTED BRIDGE

Amsterdam, the Netherlands

Using 4,500kg of steel, the pedestrian bridge offers a glimpse of what robotic-welding technology could offer our cities in the near future.

PRINTING THE BUILT ENVIRONMENT

Moving from the strategic to the practical, another facet of new technology is having an increasing impact on the solutions we offer our clients.

In most people's minds 3D printing conjures up images of small-scale prototypes intricately built up in white resin. At Arup we have bigger ideas.

In Milan, we have been working with architects CLS to develop Europe's first *3D-Printed Concrete House*. Built on-site using a portable robot, the house showcases how this exciting technology can create complex structures, speed up construction and minimise waste.

In Amsterdam, we've been applying similar technology to the challenge of building a 12 m *3D-Printed Pedestrian Bridge*.

Working in close partnership with designer Joris Laarman Lab and Dutch technology start-up MX3D, our structural engineers have explored the full potential of robotic welding to create complex structures. The results are remarkable, with the bridge's fluid raw steel form currently in full production at MX3D's specialist factory, ahead of final installation in 2019.



86%

Of 5,000 New Zealanders surveyed are concerned about water shortages

67%

Said 'doing their bit for the environment' is their main driver for saving water

APPLYING DATA TO WATER

Digital innovation is shaping better solutions in the water sector too. In the UK, we've found new ways to lessen the impact of increased flooding caused by extreme rainfall and rising sea-levels. Arup's *Floodlight Software* is a digital application that overlays flood level data onto property information data sets. The combined information can then be modelled to calculate the likely impacts and costs of flood damage.

In Hull, the firm used this new tool to help the UK Environment Agency to mitigate risks along the banks of the Humber Estuary. The resulting risk reduction business case aims to protect 250,000 people over the next 100 years.

On the other side of the world, we've used big data expertise to bring the results of an historic water survey to life. The New Zealand Water Consumer Survey was the country's first nationwide assessment of consumer attitudes. The results were highly revealing but in pure data form were hard to digest and act upon.

Our *Data Visualisation Tool* allows users to break down the data by geography and demographics, presenting a clear picture of how different strands of society think and behave when it comes to water. This information is now shaping the strategies and engagement activities of water suppliers, industry groups, and local governments – while also getting local communities talking about their own water issues.

EXPLORING PIONEERING COLLABORATIONS

One of the most fascinating aspects of digital technology is the opportunities it offers to create exciting new partnerships – particularly with those who lead their field.

Since 1958, the *National Aeronautics and Space Administration (NASA)* has been leading the way in space exploration and aeronautics research. Famed for its space activities, the organisation also looks at air travel closer to home – from next-generation commercial planes to concept designs for flying taxis. Across all this innovation noise is a major issue, which is where our expertise comes in.

NASA's aircraft simulation tools generate vast amounts of data, including noise predictions that can serve as the basis for auralizations. Our *SoundLab* technology allows this information to be realised in 3D, turning silent prediction data into a full-scale acoustic experience that can be heard and felt. NASA researchers are expected to benefit from an enhanced understanding of the impact of aircraft noise developed in conjunction with Arup. It's a pioneering collaboration allowing both organisations to better understand the impact of future air travel on the ears of people around the world, focusing specifically on the future of aircraft and airspace design, and the urban impact of flying vehicles.

“Our ground-breaking Direct Vision Standard will be the first of its kind in the world, and TfL will lead by example by not using any zero-star lorries in its future supply chain.”

Sadiq Khan
Mayor of London

OPTIMISING OUR ROADS

When it comes to embracing digital innovation, the automotive sector is further along the road than most. Three of our recent projects are proof of this.

Autonomous vehicles are widely heralded as the future of personal transport but there are significant safety and practicality issues to overcome before they are a common sight on roads. That's where the *UK Autodrive* consortium comes in.

Working in partnership with manufacturers Jaguar Land Rover, Ford, and Tata, we led connected and autonomous vehicle trials on the streets of Milton Keynes and Coventry. The largest trials conducted in the UK to date, they explored the benefits of cars 'talking' to each other and their surroundings – with connected traffic lights, emergency vehicle warnings, and emergency braking alerts among the technologies tested. Further trials have now been given the green light for the year ahead.

Staying in London, a major concern over recent years has been the rise in fatal accidents between heavy goods vehicles (HGVs), and pedestrians and cyclists. These tragic incidents are often caused by the HGV drivers' restricted view of the road. Our recent *Direct Vision* study for Transport for London (TfL) looked to find ways to make life-saving improvements.

Using simulation technology at the University of Leeds, our experts discovered that the amount lorry drivers can directly see from their cabs – rather than in mirrors or on screens – has a profound impact on road safety. This insight has already influenced TfL policy, with all HGVs operating in London now rated and licensed on our *Direct Vision* criteria from 0 to 5. We are now assessing the cost of redesigning vehicles with bigger windows to allow for greater direct vision and building a case for the EU to revise HGV standards.

▶ **UK AUTODRIVE TRIALS**
Coventry, UK

A Ford connected vehicle demonstrating its abilities to calculate optimal speed when approaching traffic lights.



Staying in London, the Mayor's ambitious goals to improve air quality and reduce carbon emissions have seen us providing critical input into the development of an iconic vehicle.

London's famous black cabs have been a feature of the capital for over a hundred years. However, new zero-emissions legislation launched in 2014 means that no additional diesel taxis can be registered to work on London's streets. A new *Electric Black Cab* was urgently needed to keep the city moving.

Our role has been to provide computer-aided engineering (CAE) services for the range extended electric vehicles. This involved a team of specialist engineers in Birmingham, London and Shanghai collaborating to assess all structural and safety related elements of the cars including durability, interior and exterior systems, noise and vibration, pedestrian and occupant safety, and crash worthiness.

Working to a tight deadline, our assessments have allowed the designers Emerald Automotive Design and manufacturers LEVC to create a best-in-class electric cab that will make a major contribution to a cleaner capital.

29 g/km

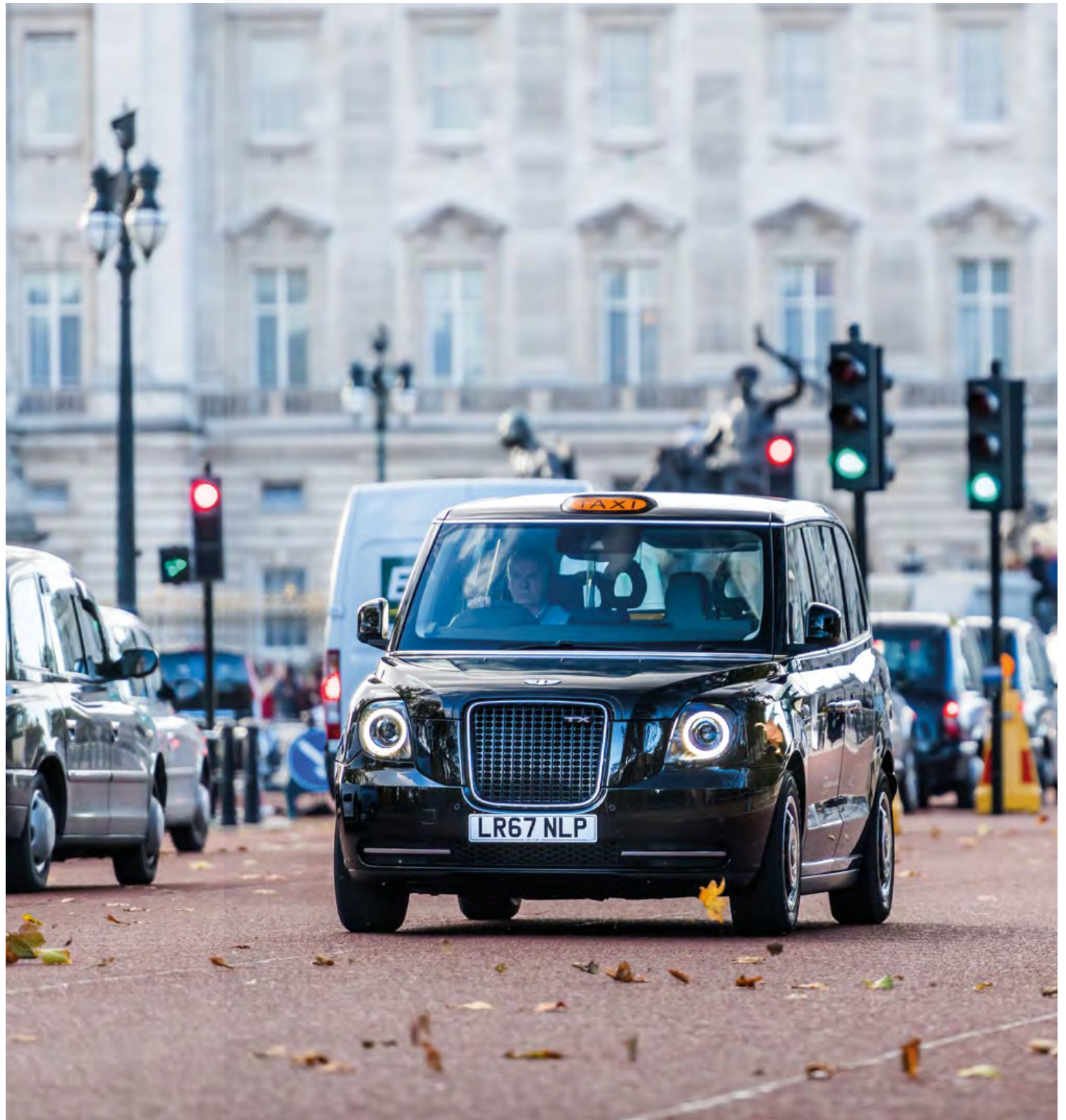
CO₂ emissions for the new Electric Black Cab are 29 g/km compared with 222 g/km for the TX4 Euro6 diesel taxi

£110

LEVC estimate drivers of the new Electric Black Cab will save an average of £110 per week in fuel costs

▶ **ELECTRIC BLACK CABS** *London, UK*

The newly licensed Electric Black Cab is able to cover at least 70 miles without producing any emissions.





ARUP UNIVERSITY & PEOPLE

Arup has always had a culture of knowledge sharing. It is something we have nurtured, celebrated, and structured through Arup University.

A culture of enquiry is the next evolution of this. As well as sharing what we do know, we encourage everyone to question what they don't. This combination of knowledge sharing and knowledge development is what Arup University is all about.

MAHADEV RAMAN

Location
New York

RE

has been rewarding to
iversity support the firm's
particularly our digital
on – through curated
rules, research and
gements. We also
portant role in advancing
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Development Goals,
content for an initial
Boston.

this, Arup University
mportant role in the firm's
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ust become increasingly
knowledge transfer.
lenge but also exciting.
n, we have developed
ative tools to achieve a
f sharing. This is what
sity does: we nurture
tion and innovation
is the firm to maintain
ive advantage. In a way,
ue that holds all our
nd regions together.



A CULTURE OF ENQUIRY

The first of Sir Ove's six aims is 'quality of work'. It's about doing everything, no matter how big or small, as well as you possibly can. For me, that is exactly the mindset Arup University is here to propagate. We do this in six connected areas: learning, research, networks, library and information services, knowledge management, and foresight.

EXPLORATION AND COLLABORATION

I'll start with learning. Our teaching ranges from online modules on technical topics to more immersive academic programmes. In my view, it is our Masters Programmes which set us apart. Rather than focusing on improving existing skills, we look for emerging or under-explored topics and bring together experts to create unique learning opportunities. This often involves collaborating with thought-leaders from outside the firm. For example, our recent Resilience module was developed alongside the Massachusetts Institute of Technology (MIT).

Arup's research is geared towards creating new knowledge and ultimately higher quality services. Staff across the firm can apply for research funding and we consistently ensure this is used to best effect.

This year, in America, we ran a prototype scheme that saw new research applications pass through a system that mapped our existing knowledge in that area. This output was then used to assess how new research should be focused. It's a great example of how innovative systems are helping us to create new thinking that builds on the great work we have already done.

586

Research projects for Arup University

£6.8m

Global spend on our research projects

A WORLDWIDE PLATFORM

Our skills networks are another important component of Arup University and increasingly steer the direction of our research. Using these forums, everyone can post questions and access the expertise of all our people. It's a global platform of ideas and collaboration that cuts across borders, disciplines, and hierarchies.

Our library and information services are set up to provide easy access to knowledge, whether that's external resources or the analysis, research, and data that make up Arup's legacy. Knowledge management is how we collect, codify, and disseminate this information.

Finally, there's foresight. This helps us understand future trends and identify areas of development. It also benefits our clients, as we share our tools and research widely. As you would expect, these six areas all overlap. For me, this is what makes Arup University unique. By bringing everything together under one umbrella, we can spark new insights, collaborations, and perspectives.

OUR FUTURE

This year, it has been rewarding to see Arup University support the firm's priorities – particularly our digital transformation – through curated learning modules, research and foresight engagements. We also played an important role in advancing Arup's commitment to the UN Sustainable Development Goals, curating the content for an initial workshop in Boston.

Building on this, Arup University will play an important role in the firm's future. In today's ever more connected world, we must become increasingly agile in our knowledge transfer. This is a challenge but also exciting. In preparation, we have developed new collaborative tools to achieve a richer level of sharing. This is what Arup University does: we nurture the collaboration and innovation needed across the firm to maintain our competitive advantage. In a way, we are the glue that holds all our disciplines and regions together.

MAKING VR A PRACTICAL REALITY

New digital platforms and applications provide exciting possibilities – and it’s critical our people understand how to realise their full potential. A recent initiative in Hong Kong demonstrates what this means in practice.

Over the last two years, Arup’s research and development team has developed a range of applications featuring augmented and virtual reality (AR and VR). Excited by the possibilities these technologies offer, their challenge was to get colleagues to embrace the applications during their daily work. The *Arup REAL Bootcamp* was a key step in achieving this.

An intensive one-day training workshop, the Bootcamp enabled participants to explore AR/VR possibilities in formats like Rhino, Revit, and SketchUp. At the end of the Bootcamp, the participants were grouped into six teams and challenged to produce AR and VR applications of their own, with the results judged two weeks later.

The submissions were impressive, demonstrating how ‘immersive visualisation’ can bring new ideas to life for both our design teams and our clients. Similar ‘learning by doing’ activities are ongoing around the world, while virtual reality is becoming a daily reality across our firm.



“The work I do here allows me to use the skills and values I learned at university and throughout my upbringing, which is incredibly rewarding. I find everyone at Arup shares this outlook. Working alongside people with an incredible desire to bring the best possible outcome to clients is mind-blowing.”

John Samineeni Jesudoss,
Graduate Engineer, Perth, Western Australia
Winner of the AITPM Young Professional of the Year Award

PEOPLE AWARDS

WILLIAM ARNOLD

Institution of Structural Engineers
Young Structural Engineering Professional of the Year

GREIG BAXTER

Institution of Civil Engineers
Jean Venables Medal

GABBY BUTERA

Australian Water Association,
Victorian Water Awards
Research Innovation Award

ROB DAY

College of Civil Engineers of Engineers Australia
Sir John Holland Civil Engineer of the Year

NAEEM HUSSAIN

Royal Incorporation of Architects in Scotland
Honorary Fellowship

JORDAN LARAWAY

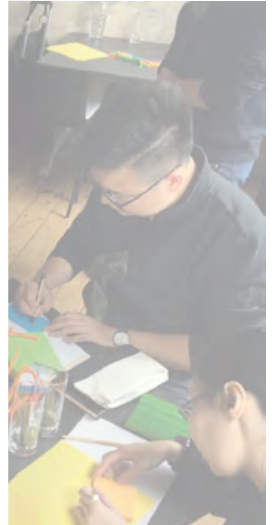
Association for Consultancy Engineering
Apprentice of the Year

PRIYANI MADAN

Australian Water Association,
Victorian Water Awards
Young Water Professional of the Year Award

FRANCESCA MACLEAN

Science and Technology Australia
Australia's 30 Superstars of STEM



For each School is different. In London, the teams looked at 'The Future of Work', while in Auckland they explored the 'Essence of Design'. Those taking part have the opportunity to collaborate on practical projects and are exposed to new ways of thinking. In a fast-paced and dynamic, our Design teams continue to strengthen the 'learning by doing' approach, finding a better way' to solve the heart of what makes a business thrive.

MAKING VR A PRACTICAL REALITY

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An intensive one-day training workshop, the Bootcamp enabled participants to explore AR/VR possibilities in formats like Revit, and SketchUp. At the end of the Bootcamp, the participants were grouped into six teams and challenged to produce AR and VR applications on their own, with the results judged a few weeks later.

The submissions were impressive, demonstrating how 'immersive visualisation' can bring new life for both our design teams and clients. Similar 'learning by doing' activities are ongoing around the world while virtual reality is becoming a reality across our firm.

AIDAN MADDEN

Engineers Ireland Excellence Awards
International Engineer of the Year

DANIELLE MCGRELLIS

Women's Engineering Society
Top 50 Women in Engineering

BELLA NGUYEN

United States American Society of Civil Engineers
John O. Bickel Award

JO DA SILVA

Institution of Structural Engineers
Gold Medal

GEORGE SCOTT

Institution of Civil Engineers
James Rennie Medal

KATE WEST

Australia National Association for Women in Construction, WA Awards for Excellence
Swan Group Crystal Vision Award

FRANK O'LEARY

Royal Academy of Engineering
Young Engineer of the Year

HE-IN CHEONG

ANNI FENG

ANSUYA OOGUR-RAMHOTA

Women in Rail
20 Rising Stars of the UK Rail Industry

ABIGAILE BROMFIELD

CORINNE SWAIN

EMMELINE REYNISH

JANE HEALEY BROWN

KIM COOPER

SUSAN CLARIS

Royal Town Planning Institute
The Planner's Women of Influence list



ARUP DESIGN SCHOOLS

Auckland, New Zealand

Our Design Schools see different disciplines coming together to explore a common design theme.



TEACHING THE ARUP WAY

A creative approach to problem solving is critical to the quality and impact of the work we do – whether we are designing a new structure or shaping a better service.

We are eager to instil this mindset in people across our firm, particularly those who are just starting their careers here. That's why we hold *Arup Design Schools*. Taught by the Arup University, this year saw 500 new members take part in Liverpool, Madrid, Auckland, Hong Kong, and Washington.

The theme for each School is different. In Liverpool, the teams looked at 'Complexity', while in Auckland participants explored the 'Essence of Design'. Those taking part have the chance to collaborate on practical challenges and are exposed to new ways of thinking.

Immersive and dynamic, our Design Schools continue to strengthen the passion for 'finding a better way' that lies at the heart of what makes Arup distinctive.

WORKING IN THE SHADOWS

Bootcamps and Schools are a critical part of what the Arup University does, but inspiring innovative thinking from our people can take other forms too.

In New South Wales, Australia, an Arup University research study has explored the untapped potential of viaducts to enhance the urban environment.

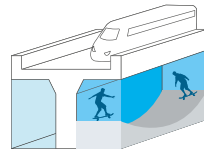
Invariably neglected and often hotspots for vandalism and crime, the space beneath road and rail structures is a wasted resource in almost every city. But does this have to be the case?

Under the Viaduct is a multidisciplinary research project that pulled together experts from our structures, landscaping, urban planning, and lighting teams to consider better uses for these under-utilised underpasses.

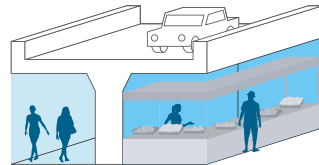
Drawing on input from our offices in Melbourne, Sydney, London, Johannesburg, and New York, the two-year study involved a range of enquiry-by-design workshops that considered what had and hadn't worked in different parts of the world.

The resulting discussion paper – created in partnership with the New South Wales Roads and Maritime Services Agency – is a great example of how Arup University funded research can open up new ideas and exciting possibilities.

INFILL



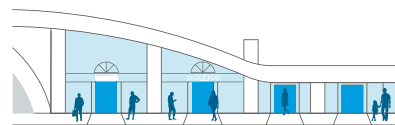
LANDSCAPE AND PUBLIC SPACES



CONNECTORS



ADAPTION



UNDER THE VIADUCT

Global research

The research project identified four opportunities for underpasses, each dependent on the stakeholder group leading the development and the population they will serve.



ZOOMING IN ON OUR PEOPLE

Arup photography rightly tends to focus on buildings, infrastructure, and the people using them in their daily lives – not those behind the projects. However, this year in Australia, a handful of Arup employees had their turn as the centre of attention.

People of Arup is a photography exhibition comprising shots of Arup staff at a wide range of project locations. Shot in black and white by our resident photographer Victor Caringal, it featured portraits and interviews with some of the talented people who make up our firm. Just as the built environment is varied and complex, those who join Arup each have their own unique background and story to share.



CLOSING THE GENDER GAP

A continued focus for Arup this year has been gender equality. Traditionally ours has been a male-dominated sector. Across the firm we are taking various steps to address this issue head-on, with the aim of achieving a better gender balance, both in terms of staff numbers and pay.

The past five years have seen steady progress in this area, with the proportion of staff who are female up 5% overall and 8% in leadership positions, but there is still room to go further. Our ultimate aim is to employ between 40% and 60% of each gender at all levels across the firm as soon as we responsibly can. We are approaching this in a number of ways:

Partnering with schools and universities to promote STEM (Science, Technology, Engineering, and Maths) subjects with the continued aim of recruiting an even gender mix at every career entry point

Publishing details of pay by gender annually

Piloting initiatives to encourage more women into leadership roles, with our senior female leaders acting as visible role models

Reviewing our promotion processes and including at least one woman on assessment panels wherever possible

Using gender-neutral language in our communications

Enhancing family-friendly policies to support all working parents

Encouraging participation in events such as International Women's Day



“Providing equal opportunity is the starting point to achieving parity, but equal reward must follow. I look forward to a day when we are not talking about gender issues but focusing on the needs of families and providing a flexible and inclusive work environment which we can all enjoy and find fulfilling.”

Dervilla Mitchell
Chair, UKMEA



COMMUNITY

Arup’s aims influence more than just our day-to-day work – they inspire us to look for greater outcomes from everything we do.

Our community engagement programme is specifically aligned with what we call ‘social usefulness’. One way we demonstrate usefulness is by pursuing projects, initiatives and partnerships which improve the lives of those most in need.

JEROME FROST

Location
London

LEAD SHAPING US

We have always encouraged others to embrace our engagement programme. We are geared around their ideas and the opportunities they present. To me, this is about more than just ‘doing good’. I believe, if we can deliver better project outcomes, we can benefit the communities we work in and the communities we work for. Our community projects give us all a perspective we can apply to our work – and our lives.

In a rewarding year, it is hard to pick a single highlight. However, one that comes to mind. Following the launch of the Global Challenge, we sought all the charities we’re working with across the globe together to complete a project. The feedback we got was invaluable. It revealed so many challenges charities face regarding funding, on the ground and the way they work in.

Charities were able to come together to build new relationships and work with each other – and we were able to see how rewarding our work can be. The impact we had been for them. The wide-reaching impact of our work in the world was gratifying to hear.

Partnerships

RISING TO GLOBAL CHALLENGES

Global in scale, our community engagement programme involves people in and around each Arup office. We have six funds, ranging from major charitable partnerships to local initiatives in the communities where we live and work. The largest is our recently established *Global Challenge Fund*. Through this, we will invest £5 million over the next five years in projects that help achieve the UN Sustainable Development Goals (SDGs), specifically those related to water and energy.

During the first year of the Fund, I'm delighted to report that 44 project teams made up of Arup staff and external partners responded to our 'call to ideas'. The projects shortlisted were then supported with incubation funding to further develop their ideas – before pitching to a panel of reviewers. The panel then selected the partnerships they believed would have the greatest impact.

Following the first two rounds, nine projects were chosen for funding. These included *Vanuatu Wash*, a local enterprise model to improve sanitation on the South Pacific island, and an innovative project aimed at improving the livelihoods of smallholder dairy farmers in Sri Lanka through *Solar Refrigeration*. In the coming year, we will launch the third round of the Fund, increasing its scope to cover even more SDGs.

2,000+

Staff took part

£3.08m

Total contribution across all six funds this year

DEVELOPMENT FUNDS

In addition to the Global Challenge Fund, we have a series of development funds: *Education*, *Carbon Reduction*, *Disaster Response & Recovery*, and *Developing Countries*. Notable projects from last year include an initiative combining access to both *Education and Clean Water* in Keur Bakar, Senegal, and our *Rapid Response to the Major Earthquake* in Mexico City.

LOCAL FUNDS

Finally, we have our *Local Engagement* fund. Here we use our time and skills to support communities and organisations in close proximity to our offices. This year, Arup staff invested £1.45 million in 132 projects and 200 activities ranging from supporting *Homeless Advocacy* in San Francisco to highlighting the *Impact of Dementia* in Melbourne.

THE WORLD SHAPING US

As a firm, we have always encouraged all our members to embrace our community engagement programme. Indeed, it is geared around their ideas and the project opportunities they bring to us. To me, this is about more than simply 'doing good'. I believe, if we want greater project outcomes, we must understand the communities we are looking to impact. Our community engagement projects give us all a broader perspective we can apply to our day-to-day work – and our lives in general.

After such a rewarding year, it is hard to pick a personal highlight. However, one day does come to mind. Following the second round of the Global Challenge Fund, we brought all the charities we're working with across the globe together for a workshop. The feedback we got was extraordinary. It revealed so many common issues charities face regarding their impact on the ground and the communities they work in.

These charities were able to come together, build new relationships, and learn from each other – and we were told repeatedly how rewarding our brokerage role had been for them. Having such wide-reaching impact across the world was gratifying to hear.

10,300+

Unpaid hours given

23

Strategic partnerships

DESIGNING TO SAVE LIVES

Those made homeless by natural disasters face many challenges. Food and shelter are urgent concerns but so is basic sanitation – specifically *Hand-Washing Facilities*.

Washing hands with soap and water is known to be one of the most cost-effective public health interventions, with the capacity to cut the transmission of life-threatening diseases like diarrhoea and pneumonia by 50%. However, providing these facilities in a form beyond an occasional bucket of dirty water is an issue that has thwarted NGOs like the Red Cross for years.

Our Global Challenge Fund sees us put £1 million a year towards supporting projects aligned to the UN Sustainable Development Goals. This year, among many other projects, we are designing a solution that ensures soap and water is readily available and easy to use, anywhere disaster strikes. With input from the British Red Cross, London School of Hygiene and Tropical Medicine, and Butyl Products, we have developed intuitive working prototypes that are now being tested in post-disaster situations. Our hope is that a robust finished product will quickly follow – improving the health of people in the most difficult circumstances imaginable.



The Aboriginal Males Healing Centre has a big vision: that all Aboriginal women and children live safe and healthy lives free of family violence.

£1m

A year is put towards supporting projects aligned to the UN Sustainable Development Goals

◀ **ABORIGINAL MALES HEALING CENTRE**

Newman, Australia
The proposed 28-bed facility, founded by Devon Cuimara (centre) will be the first specialist counselling centre of its kind.

CREATING A PLACE OF HEALING

In Australia, we are putting our design skills to use on a very different kind of project. The *Aboriginal Males Healing Centre* is an indigenous-developed programme based in the Pilbara that helps Aboriginal families dealing with domestic violence. It was set up with the aim of breaking cycles of destructive violence through clinical therapy and holistic healing.

Working in a remote region, our team was heavily involved from the outset, providing multidisciplinary

services, including structural and civil engineering, water and energy supply services plus geotechnical consultancy. The level of collaboration between Arup and the Aboriginal founders of the centre has grown throughout the project, and its funding launch will now take place at our Perth office. Once open, the centre will offer a more forward-thinking alternative to incarceration for perpetrators of domestic violence and a better future for affected families.

190km/h

Winds can hit the camp during monsoon season

60

Staff from 14 organisations trained in bamboo construction by Arup

SHELTERING ROHINGYA REFUGEES

As a result of conflict in Myanmar, more than 671,000 people from *Rohingya Communities* have fled their homes to seek refuge in neighbouring Bangladesh. The refugee camps, near the town of Cox's Bazar, have grown and merged to form the largest refugee camp in the world, now housing more than 600,000 people.

With over 56,000 Rohingyas living with local host communities and some 336,000 Bangladeshis also in need of humanitarian assistance as a result of the refugee influx, this is a crisis where over 1.3 million people are now in need of support.

A team of Arup engineers has been providing technical support and capacity-building to UN and NGO organisations working on the ground in the Rohingya refugee camps since December 2017. Our focus has been on advising and training NGOs and local teams on issues like constructing robust shelters from bamboo, dealing with unstable sloping sites, managing storm water drainage, and addressing cyclone wind damage.

It's an important task that has already resulted in practical benefits to those living in the camps, making their lives that bit more bearable in this unimaginably difficult time.



ROHINGYA REFUGEE CAMPS

Cox's Bazar, Bangladesh
Located on steep banks, the camps are made up of thousands of temporary bamboo and plastic shelters.

HELPING A CITY RECOVER

When *Hurricane Harvey* hit Houston in August 2017 the resulting flooding destroyed or damaged 135,000 homes, as well as much of the city's domestic water, sewage pumping, and electrical systems.

A massive clean-up operation needed to be coordinated across the city and the whole region. Sadly, the centre point for that process, Houston City Hall, was badly damaged too. Effective action was urgently required, which is where our team in South East Texas stepped in.

With engineering projects in process at City Hall and a strong knowledge of the building's service systems, Arup was best placed to put a repair and replacement plan into action. Taking a project direction role, we advised City Hall officials, directed contractors, sourced replacement equipment from across North America, and fast-tracked a process that would usually take 9-12 months into just a week.

It was a complex task requiring a great deal of collaboration and commitment but our team got the job done, ensuring that City Hall could function again as the epicentre of Houston's wider recovery.

ENABLING CRITICAL SUPPORT

Homelessness is a growing issue for communities around the world. In the US, a federal study found over a half a million people were homeless on a single night in 2018, a rise of 0.7% over the previous year. Rising rents and a lack of affordable housing are drivers for this major social issue.

Many people facing homelessness lack sound advice, particularly regarding their legal rights. That's where the Bar Association of San Francisco's *Homeless Advocacy Project* helps, providing over 1,500 people a year with free legal advice on issues such as benefits, eviction, and immigration.

It's a vital service that's making a major difference to people's lives. However, the Project's work was being severely hampered by its own accommodation. Specifically, staff and volunteers were struggling through cold winters and hot summers with no heating or cooling systems in their Justice and Diversity Centre (JDC).

Through a staff application to our Community Engagement Programme, Arup funded a team in the local office to solve the problem. They designed a completely new heating and ventilation system for the JDC building, alongside a major electrical upgrade. They also oversaw the project through construction, transforming conditions for all the building's users, as they continue their life-changing work.

"It was truly a team effort to prepare City Hall and the Annex for today. These companies came together working alongside the General Service Department to do tremendous work under a tight, tight timeline."

Sylvester Turner
Houston Mayor



▲
**MINIPLEX
 STRUCTURE AT
 THE LONDON
 ARCHITECTURE
 FESTIVAL**

London, UK
 Arup staff working with students to explore the structural possibilities offered by Miniplex sheets.

**INSPIRING TOMORROW'S
 DESIGNERS**

A key community task for Arup is showcasing the exciting possibilities architecture and engineering can offer school-age students. Centred on the principle that 'doing is always better than telling', a recent initiative in London is a prime example of the way we bring this story to life.

Partnering with architects AHMM and contractor Knight Harwood, we led an *Interactive Discovery Project* with students aged between 12 and 18 that was showcased at the London Architecture Festival. The project centred on exploring the structural possibilities of Miniplex sheets. These modular plastic sheets automatically curve when they are clipped together. Quick to assemble and infinitely flexible, over 7,000 sheets were used to create an exciting pop-up sculpture that was displayed for a week directly outside St Paul's Cathedral.

Further north in the UK, we teamed up with Imagineer Productions and four secondary schools to help students create a structure to mark the centenary of the Cathedral and Diocese of Coventry and the fifth *Festival of Imagineers* – a week-long event aimed at getting young people interested in science, technology, engineering and mathematics (STEM) subjects through art and design.

The students created *Hupla*, a 19 m installation made from 1,000 hula hoops reaching from floor to ceiling. Initial inspiration for the project came from seeing children stacking hula hoops during a family trip to the park.

A year in the making, we first created a virtual reality model of the concept before building a scale model at our Midlands Campus. The structural assessment revealed that a full height hula hoop tower would fail under its own weight. Therefore, an alternative design was created using a steel wire frame twisted elegantly between two large steel hoops. Our structural engineers then used parametric modelling to create the geometry.

Plastic hoops decorated with messages from the school students were used to clad the final structure. Once positioned within Coventry Cathedral, the installation took 18 hours to construct and was, without a doubt, one of the highlights of the festival.

Incidentally, the current St Michael's Cathedral, built next to the remains of the old Coventry Cathedral, was one of Sir Ove Arup's personal achievements.

CLEANER COOKING IN KENYA

Across the developing world, three billion people cook on open fires or rudimentary cookstoves. This exposes them to hazardous indoor pollutants – a primary cause of respiratory disease. It also sees large amounts of carbon entering the earth's atmosphere, with obvious impacts on climate change.

Our recent partnership with ClimateCare seeks to find a solution to this significant problem. Specifically, it aims to bring *Clean Cooking* to 100,000 people in Kenya over the next three years – improving health and reducing carbon emissions.

Modern, energy efficient cookstoves are available in Kenya – but are financially out of reach to many. Using ClimateCare's revolving fund model, low-income households will be able to buy this life-improving technology by accessing low interest loans. The fund model allows for a longer term, systemic approach to providing support, giving many more people access to clean, sustainable technology.

▼
**CLEAN COOKING
 INITIATIVE**

Kenya
 A clean-burning ethanol cooker in use.





SUSTAINABLE DEVELOPMENT

As a firm we aim to shape a better world. The UN Sustainable Development Goals (SDGs) will help us define what ‘better’ looks like.

It is important to remember that we are starting with a blank piece of paper. Sustainability has been at the heart of our firm for the past two decades. In fact, many of the projects we are already making contributions to sustainable development, such as our work on the circular economy with The Ellen MacArthur Foundation (p41), and our partnerships with the C40 cities. This type of thinking that will define our future.

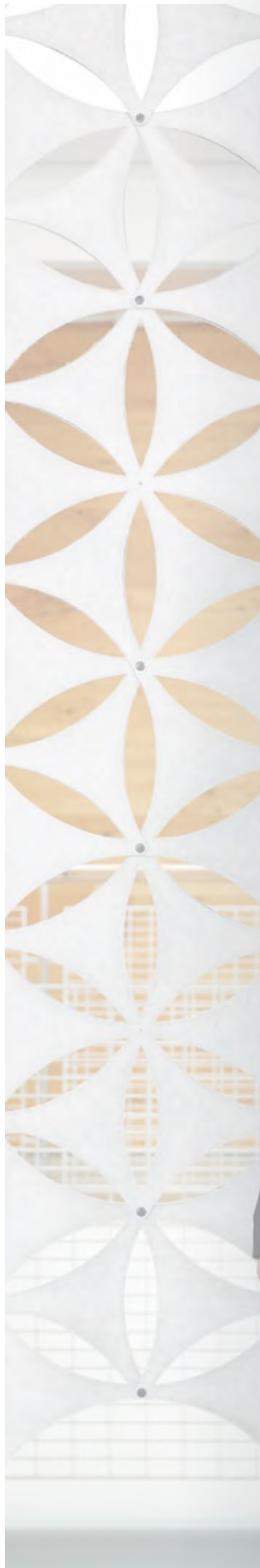
COALITION

It is important to have a formally recognised coalition, with the important aligning with the firm and put a leadership in place to drive this change. Top-down leadership is not enough. For us to inspire and partners and make development ‘business as usual’ we must unleash the creativity and talent of all our people, through a coalition of committed people across the firm.

It is not just talk is over. This is not about mental change. It’s about action. Get it right and we can shape the next 30 years of our firm. Help our people, clients, and communities prosper.

JO DA SILVA

Location
London



SHAPING A SUSTAINABLE FUTURE

I don't think I can overstate just how important the UN SDGs are. We only have one planet, and it's reached a tipping point. Increasing urbanisation and the emerging middle class have generated wealth for many, yet rapid consumption and unsustainable production methods mean resources are running out, waste fills our oceans, and climate change is no longer just an existential threat.

Radical change is required – from all governments and all businesses. The UN SDGs are a roadmap for this change. Devised with input from five million people, they represent a progressive new path, a call to end poverty, tackle climate change, protect our planet, and ensure everyone can enjoy peace and prosperity. Crucially, they recognise the importance of business in making these changes a reality.

With all this in mind, Arup made a formal commitment to align our business with the 17 SDGs – expanding our capacity to create value for our clients and protect our planet. It is a significant step, which I am confident will have real impact in the years ahead.

A STRATEGIC CHOICE

The SDGs will act as a unifying thread for us. It doesn't matter if we are analysing acoustics or designing high-speed rail links, all our people will share the same purpose: using our ingenuity and business-sense to contribute to sustainable development. I would also say that if the SDGs are our common purpose, the firm's digital transformation is at the heart of achieving it. These are our two most important agendas, and they go hand-in-hand.

Committing to the SDGs is also a strategic choice for the firm to stay relevant. It allows us to build for the long-term and embrace new opportunities, partnerships, and client relationships in a world that will increasingly depend on innovative ideas, designs, and technologies as resources dwindle.

It's important to remember that we are not starting with a blank piece of paper. Sustainability has been at the heart of our firm for the past two decades. In fact, many of the projects in this report are already making meaningful contributions to sustainable development, such as our work on the circular economy with the Ellen MacArthur Foundation (page 41), and our partnerships with the C40 cities (page 37). It's this type of thinking that will increasingly define our future.

A GLOBAL COALITION

Last year, we formally recognised just how important aligning with the SDGs is and put a leadership structure in place to drive this change. However, top-down leadership alone isn't enough. For us to inspire our clients and partners and make sustainable development 'business as usual', we must unleash the creativity and enthusiasm of all our people, mobilising a coalition of committed activists across the firm.

The time for talk is over. This is not about incremental change. It's about firm-wide action. Get it right and we will define the next 30 years of Arup – and help our people, clients, and planet prosper.

99.3%

Of staff in offices certified to ISO 14001 Environmental Management System

9 years

Greenhouse gas emissions per full-time employee fell for the ninth year in a row to 3 tCO₂e per person

208 kWh/m²

Energy consumption per square metre, down from 236 kWh/m² in 2017



SHAPING GLOBAL WATER RESILIENCE

Water is the lifeblood of all cities, yet supplies are coming under strain. Growing populations and rising living standards are driving demand for water ever higher. Meanwhile, a changing climate is making extreme events, from droughts to floods, an increasingly common occurrence, leaving cities of all kinds vulnerable to water stress.

Against this background we are working with the Rockefeller Foundation to develop a *City Water Resilience Framework* that will help cities manage and plan their water needs more effectively.

Through the 100 Resilient Cities Network, five cities were selected to partner in the development of the

Framework. Amman, Cape Town, Hull, Mexico City, and Greater Miami were chosen because of their diversity of population, location, and economic status, plus their commitment to taking a strategic approach to resilience.

Activity is currently focused on analysing each city's unique water needs. We and our partners, Alliance for Global Water Adaption (AGWA) and Stockholm International Water Institute, will then develop strategies and share our findings at a global event. This will give all the cities who applied to be part of the project the chance to benefit from innovative new approaches to water management.

RESILIENT CITIES

Mexico City, Mexico
Part of the 'Conflicts of an Urban Age' exhibition displayed at our London office, this image shows Mexico City's dramatic urban sprawl.

MOVING NEW YORK TOWARDS PARIS AND ZERO CARBON

In last year's report, our Chairman described our work with the C40 Cities Group, developing the *Deadline 2020: How Cities will get the job done* research.

The report quantified the contribution that cities need to make to achieve the goals of the 2015 Paris Climate Agreement. It concluded that to prevent runaway climate change, city emissions across the world need to peak by 2020, then decline to an average of three metric tons of CO₂ per capita by 2030. Finally, they must hit zero by 2050.

Meeting those challenging targets is now the C40's overriding aim. Doing so requires bespoke Climate Action Plans for every major city – responding to specific local factors and building on global best practice. To support cities in achieving their goals, Arup and C40 co-created the *Climate Action Planning Framework* which sets the standard for city climate action plans that meet the objectives of the Paris Agreement.

New York City (NYC) Mayor Bill de Blasio has committed the city to the Paris Agreement targets, the first city in the world to do so. As a C40 member city, NYC sought guidance on how to enhance their existing climate plan. We contributed to the draft plan and advised specifically on its zero carbon ambition.

Following the plan's release, Arup worked with the city on developing a tool to enable all city agencies to quantify their greenhouse gas (GHG) emissions, catalogue Energy Conservation Measures (ECMs), analyse cost impacts, and scenario plan GHG reductions. The tool is set to be adopted by the city's 30+ agencies and departments, and will allow them to plan and track their progress.

We are now performing a similar role with other cities in the C40 network across America, the Middle East, and Australia.

"I am proud that New York City will play its part and that we are joining in common cause with hundreds of local governments around this nation and the world. Together, we will show that the people will solve this problem at the grassroots."

Bill de Blasio,
New York City Mayor

“Madrid Nuevo Norte is a cutting-edge project that will become a benchmark for sustainable urban regeneration worldwide. It is a leading example of a new approach to urban design coming from a true public-private collaboration. Based on a high-density urban development model and offering a mix of uses, the area will be served by a powerful public transport network, and will undoubtedly help improve the quality of life for Madrid residents.”

Antonio Béjar
Distrito Castellana Norte Chairman and CEO

BUILDING A GREENER CITY

Madrid Nuevo Norte is one of Europe’s largest urban regeneration projects and represents a great opportunity to place Madrid among the world’s most sustainable cities. Unveiled under the slogan ‘Madrid’s project, Everyone’s project’, it places the needs of the city’s people at the heart of its design philosophy.

Spread over 300 hectares, the development will transform obsolete industrial land historically split in two by rail tracks. These will now be spanned by three bridges, a road tunnel, and a pedestrian and cycling footbridge – immediately creating a much more human-friendly environment.

The layout of the development’s streets is designed to promote cycling and public transport, while new green spaces – containing many newly planted trees – will integrate with existing parks to create a lush green corridor. Containing 13 km of bike paths, it will link the city with El Monte de El Pardo, the largest forest in Madrid.

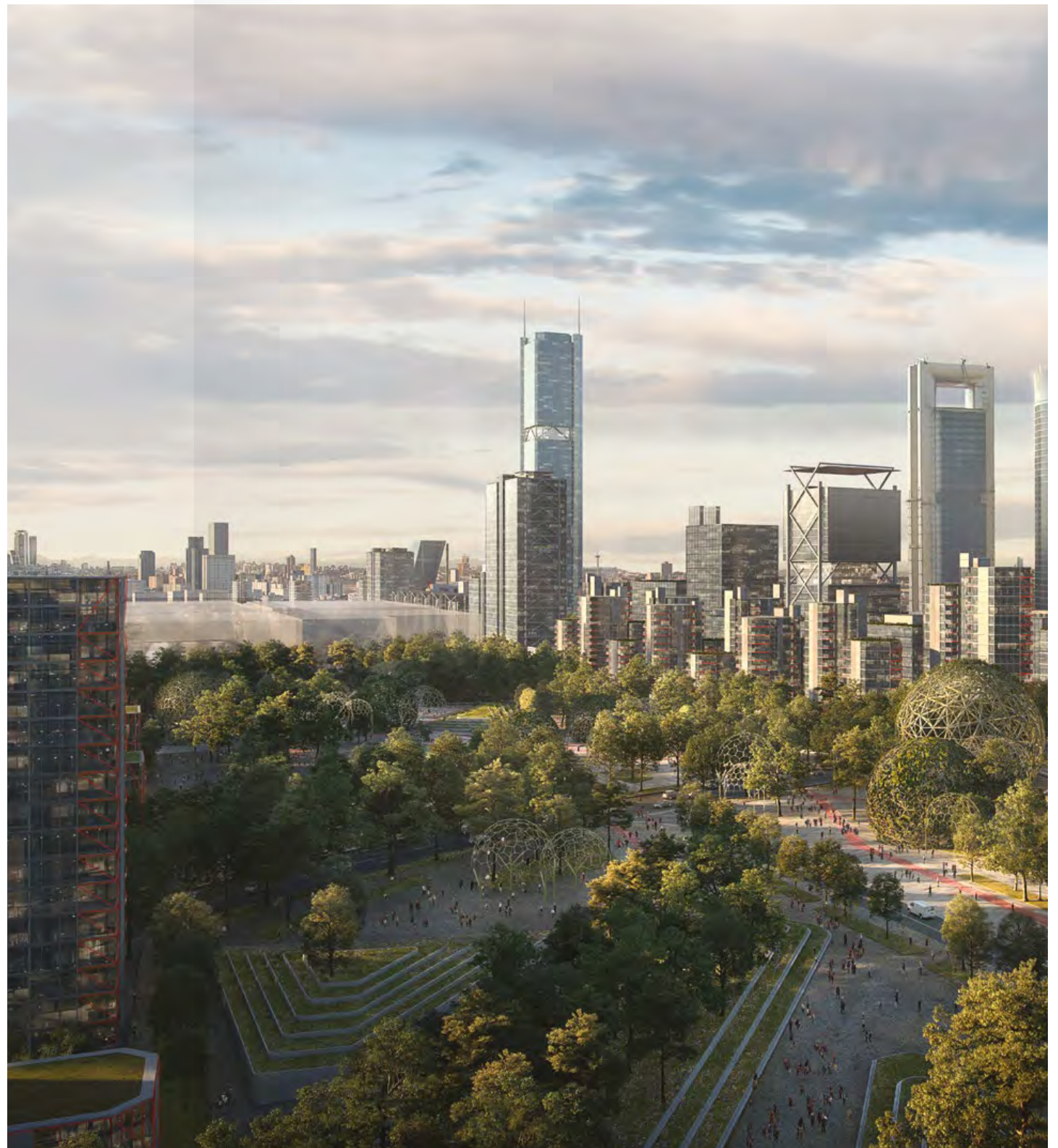
Arup’s role in the project has been extensive. As the private developer’s advisor for Distrito Castellana Norte it spans town planning, sustainability, urban innovation and mobility consultancy, plus project and programme management. Madrid Nuevo Norte will boost the city’s economy, attract inward investment, and generate new employment opportunities. Perhaps more importantly, it will set new standards for sustainable urban development, with the needs of people considered above all else.



MADRID NUEVO NORTE

Madrid, Spain

A new concept of urban sustainability.





SHARING THE BENEFITS OF A CIRCULAR ECONOMY

For the last two years Arup has been working with the Ellen MacArthur Foundation to explore circular economy principles across the built environment.

A recent publication shows how much of this thinking is taking shape. Entitled *The Industrial Resolution*, it is the result of our research into closed loop design, manufacturing, and re-use in the field of products, buildings, technology, furniture, vehicles, and packaging. Thoughts drawn from historic and contemporary case studies provide insight, demonstrating how physical products can be refined to reduce the impact they have on our planet. Drawing on a wealth of fresh thinking, it is designed to move us towards a point where circular economy principles become standard built environment practice.

If *The Industrial Resolution* presents a compelling view of circular economy principles, a recent project in the Netherlands shows what some of these ideas can mean in practice.

The *People's Pavilion* is a temporary structure designed in collaboration with architects Overtreders W and Bureau SLA as part of the Dutch Design Week festival. Constructed entirely from borrowed materials, it was conceived as an exemplar of circular economy thinking. This entailed dismantling the building after the event, with all of the components returned to suppliers in their original state.

The key challenge for our structural engineering and sustainable design team was to design a safe building without damaging the materials in any way. This meant devising a construction technique that didn't use glue, screws, or nails.

The frame was constructed with standard off-the-shelf timber sections and tied together with steel straps to make longer and stronger composite elements. The columns consisted of 7m prefab concrete foundation piles, while steel rods taken from a demolished office building were reused as cross bracing. The whole structure is tied together using high capacity ratchet straps designed to create a safe and robust structure capable of withstanding strong wind conditions. The glass roof was borrowed from a greenhouse supplier, while the distinctive coloured shingles were made from plastic waste collected from the inhabitants of Eindhoven.

With close to a zero-carbon footprint, it's an ingenious building that shows exactly what's possible if you approach building design with the intent of not wasting anything.

PEOPLE'S PAVILION Eindhoven, the Netherlands

The shingles are made from recycled plastic waste, giving the pavilion its unique colour scheme.

Following the sun, our journey this year begins in Tonga, and takes in Australia, Singapore and Malaysia. Across all these countries we have pushed the boundaries of sustainable development. From the adaptive reuse of materials to helping a whole country transition to clean energy, it's been a year of progressive innovation.



▶ **QUAY QUARTER TOWER**

Sydney, Australia

A striking and sustainable development at the centre of Sydney's revitalised Quay Quarter.

REJUVENATING A FAMOUS HARBOUR

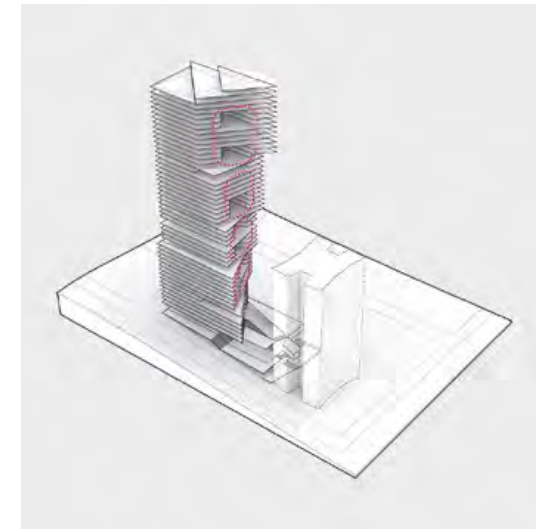
Quay Quarter Tower, a sophisticated and contemporary office development, will form the centrepiece of AMP Capital's Quay Quarter. Arup and Danish architects 3XN were selected to design this new city landmark as sustainably and efficiently as possible.

When any major urban development begins with a big demolition process a huge amount of valuable resource is wasted. That's why we are increasingly advocating a concept called 'adaptive reuse'. In Quay Quarter, this entailed the careful repurposing of 68% of the existing 1970s tower as the core of the new structure.

This approach saved an enormous amount of embodied energy – the equivalent of 10,000 flights from Sydney to Melbourne. Combined with innovative sun-shading hoods that ensure the building's façade will minimise energy use, it's a prime example of smart, sustainable thinking resulting in tangible benefits.

"We've found sustainability is increasingly important to the market, leading to higher demand for green buildings, lower vacancy rates, and better returns for our investors."

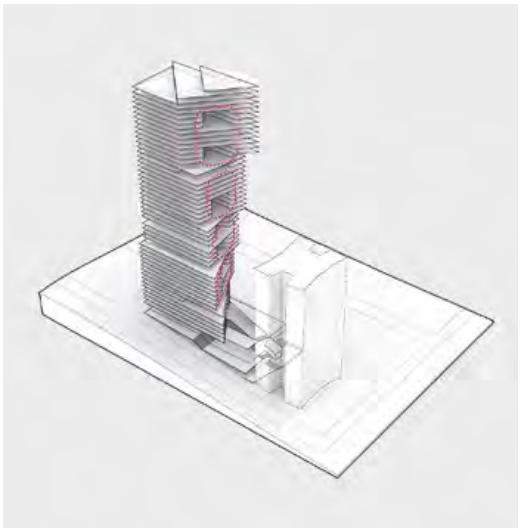
Chris Nunn
AMP Capital



QUAY QUARTER TOWER

Sydney, Australia

The twisting angular design – a series of stacked 'vertical villages' designed around atria – creates a different vista of Sydney from each stack. The shading folds and tapers to follow the sun as it moves from east to west – minimising glare, enhancing thermal comfort, and preserving views of the city below.



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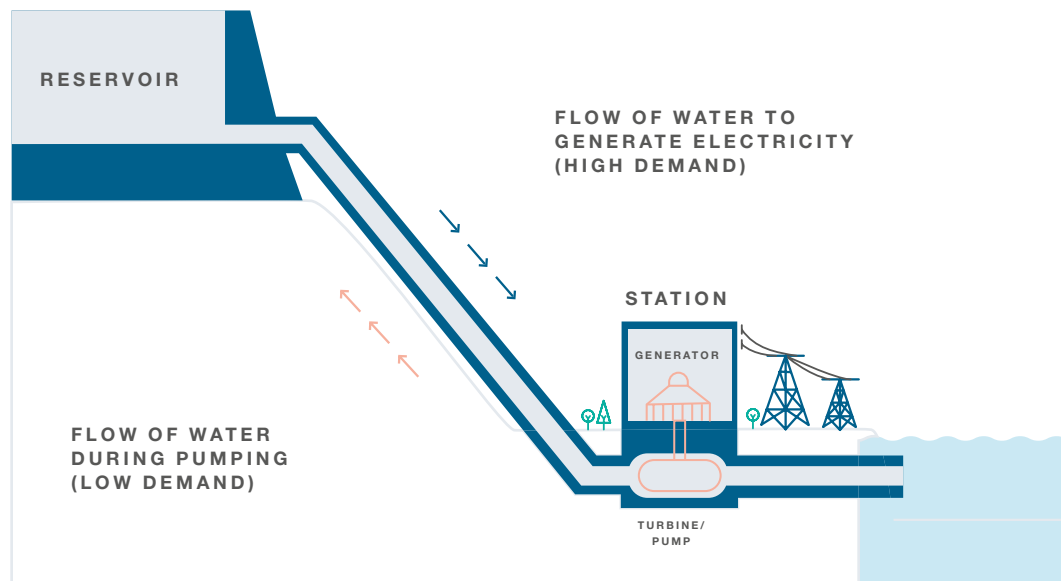
MAKING RENEWABLES MORE DEPENDABLE

Meeting demand is a major challenge for renewable energy. Solar and wind are critical sources, but the energy they produce can't always keep up with the early evening peak in demand, caused by millions of households cooking dinner, switching on their heating, or watching TV.

Pumped Hydroelectric Energy Storage (PHES) addresses this issue. During off-peak periods, low-cost renewable energy is used to pump freshwater from a lower reservoir to a higher point where it is then stored. When demand reaches its peak, the water is released through hydro electric turbines to provide power when it's needed most. It's an ingenious solution, but what do you do in areas of the world where freshwater is at a premium?

Addressing this constraint, Arup, in collaboration with the Melbourne Energy Institute (MEI), undertook research into using seawater instead – with funding provided by the *Arup Global Research Challenge*. The study found there is potential in Australia to construct artificial reservoirs – known as 'turkey-nest dams' – to facilitate PHES, with coastal seawater replacing the lower, freshwater reservoirs.

With South Australia recently experiencing state-wide blackouts, EnergyAustralia, one of Australia's largest utilities, recognised the potential for this new technology to help solve supply issues. In 2017, EnergyAustralia, Arup, and MEI partnered to deliver a detailed feasibility study for a 100-250 MW PHES plant at Cultana, near the tip of the Spencer Gulf in South Australia. It's a compelling prospect, reimagining renewables to ensure businesses and consumers can receive clean energy when they need it most.



RAISING THE BAR IN SINGAPORE'S CBD

At 290 m, *Tanjong Pagar Centre* is now the tallest building in Singapore. Spread over 156,000 m², it combines commercial, residential, retail, hotel, and urban park amenities. The development is also fully integrated with the Tanjong Pagar Mass Rapid Transit (MRT) metro station, providing efficient access to a new, vibrant space to live, work, and play in the Central Business District (CBD).

Direct access from the MRT was achieved by connecting the building's three-level basement to the station's structure. By phasing the construction, the basement structure also doubled as a retaining wall, allowing construction to continue with minimal disruption to existing MRT operations.

This dynamic new skyscraper is at the forefront of sustainable development in Southeast Asia. Each of its roofs are installed with PV panels that capture sunlight for renewable energy. Rainwater is also harvested from the roofs to irrigate the extensive surrounding greenery, resulting in almost zero storm water run-off. On top of this, fresh air is delivered to interior spaces at a rate 30% higher than conventional office buildings.

Tanjong Pagar Centre has been awarded both Green Mark Platinum and LEED Platinum certifications – setting higher standards for sustainability and innovation for future tall building developments in Singapore.

290 m

Tanjong Pagar Centre is the tallest building in Singapore

14,000 m²

Size of the urban park built as part of the development

TANJONG PAGAR CENTRE

Singapore

Tanjong Pagar Centre was designed in collaboration with architects Skidmore, Owings and Merrill, and Architects 61.

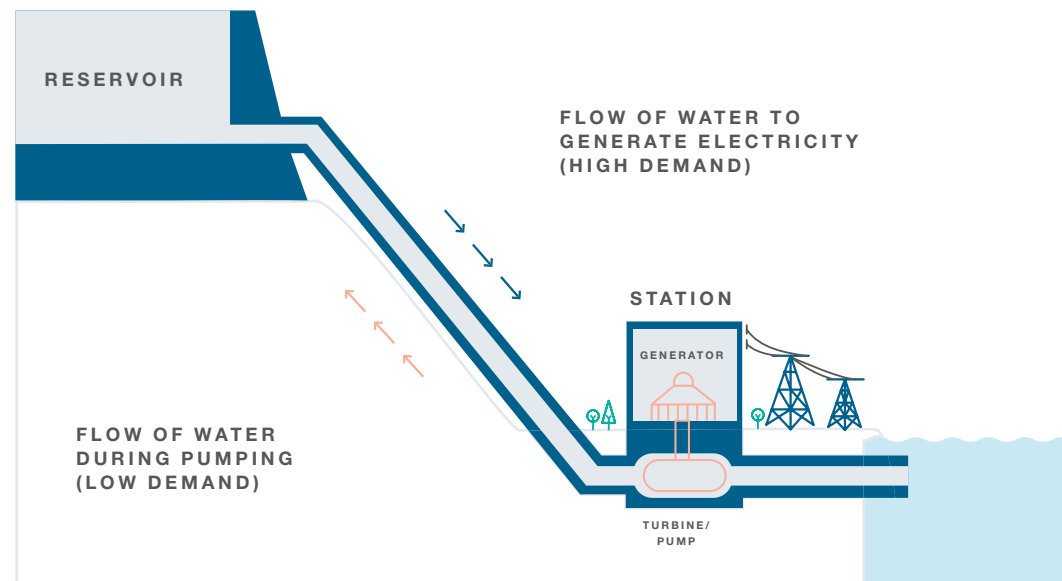
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RAWANG BYPASS

Rawang, Malaysia

The Taman Warisan forest is home to an array of protected flora and fauna, including the nearly extinct Giam Kanching trees which are only found in this part of the world. The elevated section of Rawang Bypass cuts through the forest reserve with minimal deforestation.

DRIVING INNOVATIVE HIGHWAY DESIGN

Across the world, highways are an important catalyst of economic growth. It's critical they are built with a clear focus on their total impact – economic, social, and environmental. Two projects we've completed this year embody this approach.

In Malaysia, the new 18 km *Rawang Bypass* was needed to reduce congestion in the town of Rawang and drastically improve travel time between Serendah and Kuala Lumpur. The principal challenge was building a 3.2 km elevated section through the forest reserve of Taman Warisan.

Deforestation caused by the construction process was a particular concern. Our solution was to use a Moveable Scaffolding System (MSS) – the first time this technology had been used in Malaysia. The MSS allowed the most intrusive elements of the structure – the beams and slabs – to be cast at deck level, with just a narrow corridor beneath facilitating construction of the bridge piers. Quick, reliable, and economical, this system enabled the elevated highway to be constructed with minimal impact on the precious surrounding ecosystem.



50 m

A corridor just 50m wide was cleared through the forest during construction

30 mins

The new highway reduces travel time between Serendah and Kuala Lumpur from two hours to a mere 30 minutes, significantly enhancing economic development in the area

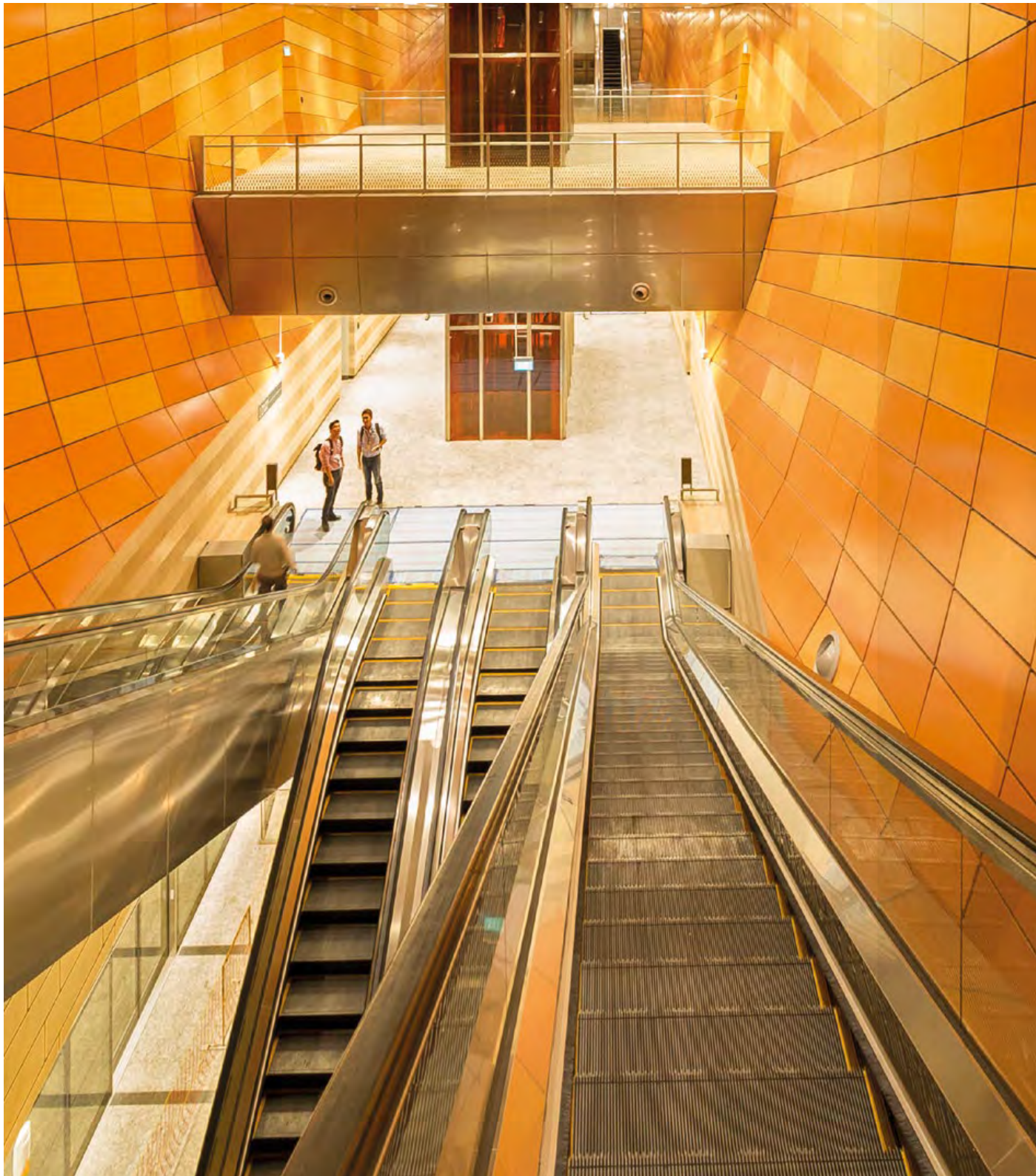
60 m

The tallest pier height from deck to ground level

In Queensland, Australia, Arup is working in a joint venture with Jacobs on the *Bruce Highway Upgrade*. This AU\$813 million project involves the construction of a six-lane divided highway and major upgrades to the Caloundra Road and Sunshine Motorway interchanges.

As well as providing a significant boost to the Sunshine Coast economy, the upgrade will also result in tangible improvements to road safety for drivers, cyclists, and pedestrians alike.

A key feature of our design is the use of an innovative Diverging Diamond interchange to replace the existing Caloundra Road interchange. This will reduce impact on the Mooloolah River National Park, minimise congestion and, most importantly, increase safety in an area which currently has one of the highest accident rates in Australia.



DIGGING DEEP FOR LESS CONGESTION

October 2017 saw the opening of the *Downtown Line 3* on Singapore's driverless Mass Rapid Transit (MRT) metro system. This is the final phase of a 42 km project linking the eastern and north-western neighbourhoods to the Central Business District and Marina Bay areas at the heart of the city.

Arup started work on this phase in 2008, developing the alignment design for the entire 21 km stretch. A year later we produced a full-detail design for five stations and 5 km of twin tunnels.

Pushing the boundaries of innovation, we used Steel Fibre Reinforced Concrete (SFRC) lining for the tunnels of *Downtown Line 3* – a first in Southeast Asia. This saved costs during construction, increased durability in the long-term, and improved fire safety.

One key challenge of the project was working within a dense urban environment – both above and below ground. Bencoolen Station exemplified these difficulties. The deepest MRT in Singapore at 43 m, its six levels were constructed adjacent to the operational Circle and North-South Lines, a complex network of underground infrastructure, and in close proximity to commercial and cultural buildings.

energy was a state-owned
rating the electrical
network for Western
llawarra. Our specialist
Investor Advisory team
an international consortium
arie Infrastructure and
nd AMP Capital on their
US\$7.6bn bid for a 50.4%
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or the AU\$16bn lease
2016. In total, over
s been freed up by the
y asset privatisation
These funds can now
l into infrastructure
uding a new metro rail,
ool, and hospital.



BENCOOLEN STATION

Singapore

The deepest MRT station in Singapore, it takes five escalator rides to get back to street level.



The project also involved diverting a stretch of the Singapore River to protect the tunnel from flooding during construction. Done in stages, vacant land adjacent to the river was converted into an empty channel to divert the river flow. The river's embankment walls and other objects interfering with the tunnels were then removed to allow the tunnelling works to pass below the river unobstructed. Once construction was completed, the river was diverted back along its original course.

The benefits of the new line are twofold: travel time from the neighbourhoods to the downtown district has been cut in half. Meanwhile, in addition to wider pavements, all-day bus lanes, and dedicated cycling paths, the new line has contributed significantly towards Singapore's goal of creating a world-class transport system.



@JCHRSTY • 2018

Bencoolen MRT Station

Getting lost and enjoying the adventure ✨

DELIVERING A MIX OF ENERGY EXPERTISE

Located in the South Pacific with a population of just over 100,000 people, Tonga is a small country with big energy plans.

At present, 80% of the country's energy comes from diesel, while fuel accounts for 25% of all imports by value and 10% of GDP. This leaves Tonga vulnerable to oil price volatility and ultimately in an unsustainable position – both economically and environmentally.

We are working with Tonga Power Limited (TPL), Tonga's energy provider, to develop an *Energy Roadmap* based on a carefully balanced mix of renewable energy sources: wind, solar, and Battery Energy Storage Solutions (BESS). The immediate aim is to achieve a 50% renewable energy target by 2020, with an ever increasing deployment over time. Meeting this ambitious goal won't just strengthen and protect Tonga's energy supply, it could transform the country's whole economy.

Elsewhere in the region our experts have helped address a very different sort of energy challenge.

Throughout the world there is pressure on regional governments to fund crucial transport and social infrastructure. One way to do this is to release capital from mature assets. That was the plan in New South Wales (NSW), Australia.

Endeavour Energy was a state-owned company operating the electrical distribution network for Western Sydney and Illawarra. Our specialist Business and Investor Advisory team worked with an international consortium led by Macquarie Infrastructure and Real Assets and AMP Capital on their successful AU\$7.6bn bid for a 50.4% stake in this business.

Arup helped analyse the opportunities and risks associated with the business, providing a range of optimisation, regulatory, technical, and environmental due diligence services. We also helped develop and present the client's business plan to NSW State Treasury and have subsequently worked with Endeavour Energy's new management team to implement their business plan across a range of initiatives.

We previously provided advisory services to the successful bidding consortium for the AU\$16bn lease of Ausgrid. In total, over AU\$23bn has been freed up by the State's energy asset privatisation programme. These funds can now be reinvested into infrastructure projects, including a new metro rail, highway, school, and hospital.

50%

Tonga plans to get half of its energy from renewable sources by 2020

Staying in the East, it's been a year of significant achievements in Japan, Greater China, and Vietnam. From the world's largest airport terminal to the longest sea crossing, our work is helping this most ambitious of regions push the boundaries of invention and ingenuity.



▶
**HONG KONG-ZHUHAI-
MACAU BRIDGE**

The world's longest sea crossing and fixed link.

46 m

The cone structure has a diameter of 10 m at the base unfurling to 46 m below the roof

PAYING HOMAGE TO NATURE

In 2013, Japan's cone-shaped volcano, Mount Fuji, was granted UNESCO World Heritage status on the basis that it had 'inspired artists and poets and been the object of pilgrimage for centuries.'

The inspirational nature of the mountain also lies at the heart of our engineering design for the recently opened *Mount Fuji World Heritage Centre*. Created in collaboration with Shigeru Ban Architects, the building's dynamic funnel-shaped form mirrors the mountain beyond.

Bringing the design to life meant overcoming a significant engineering challenge. Seismic volatility means that experimental building shapes like this are rarely seen in Japan. To address this issue our team recognised that the funnel needed to be the primary building structure.

Constructed through an efficient system of steel lattices, it resists seismic forces and bears the gravity loads for the entire volume including the roof plate and observation hall above. The result is a structure that is as robust as it is beautiful.

A different, subtler, inspiration is another key feature of the building. Our early stage research found that the abundant spring water that cascades down the mountain maintains a temperature of 15°C all year round. By effectively utilising its temperature potential in the building's heating and cooling systems, we managed to reduce energy consumption by 20% – an elegant engineering solution for an equally elegant structure.

MOUNT FUJI WORLD HERITAGE CENTRE

Honshu, Japan

One of the highlights of the Heritage Centre can be found within its funnel-shaped structure. This contains a 193 m spiral slope where visitors can simulate the experience of ascending Japan's tallest mountain.



12%

Between 1999 and 2016
Macau's GDP rose from
\$6bn to \$45bn at an
annualised rate of 12%

2.6 million

The number of people who
visited Macau last year, a
9.4% year-on-year rise



SHAPING HIGH STAKES GROWTH

From world-class resorts to critical planning and infrastructure projects, for the past 15 years Arup's design and engineering expertise has helped drive Macau's rapid progress from national to international tourist destination.

Our first project here was the *Sands Macau* in 2004. Since then, we have worked on further large-scale entertainment projects, including the futuristic *Morpheus Hotel*, in collaboration with Zaha Hadid Architects.

Over the past decade our portfolio has expanded to planning and infrastructure projects. These include *Tai Tam Hill Tunnel*, *Light Rail Transit East Line*, and *Seac Pai Van*. This year saw another landmark with our appointment to design the fourth bridge

between Macau and Taipa – building on our extensive work over the last eight years on the *Hong Kong–Zhuhai–Macau Bridge and Tunnel* projects, (see overleaf).

Last year saw us win the opportunity to bring all of our multidisciplinary skills together. The *Macau Urban Masterplan* project will see the firm shaping the development of the city as a whole, including the artificial island of the Hong Kong–Zhuhai–Macau Bridge and the 85 km² of territorial waters under the city's jurisdiction. It's a chance to take a holistic view of Macau's future, building on our impact over the past 15 years.

MACAU

Greater China

Arup is contributing unrivalled engineering and consulting expertise to change the cityscape of Macau and drive the city's economic development.

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HONG KONG-ZHUHAI-MACAU BRIDGE

Greater China

This is the first major, combined, bridge and tunnel sea-crossing project in China, creating a vital driver for growth in the Pan-Pearl River Delta region.

STRENGTHENING HONG KONG'S CONNECTIONS

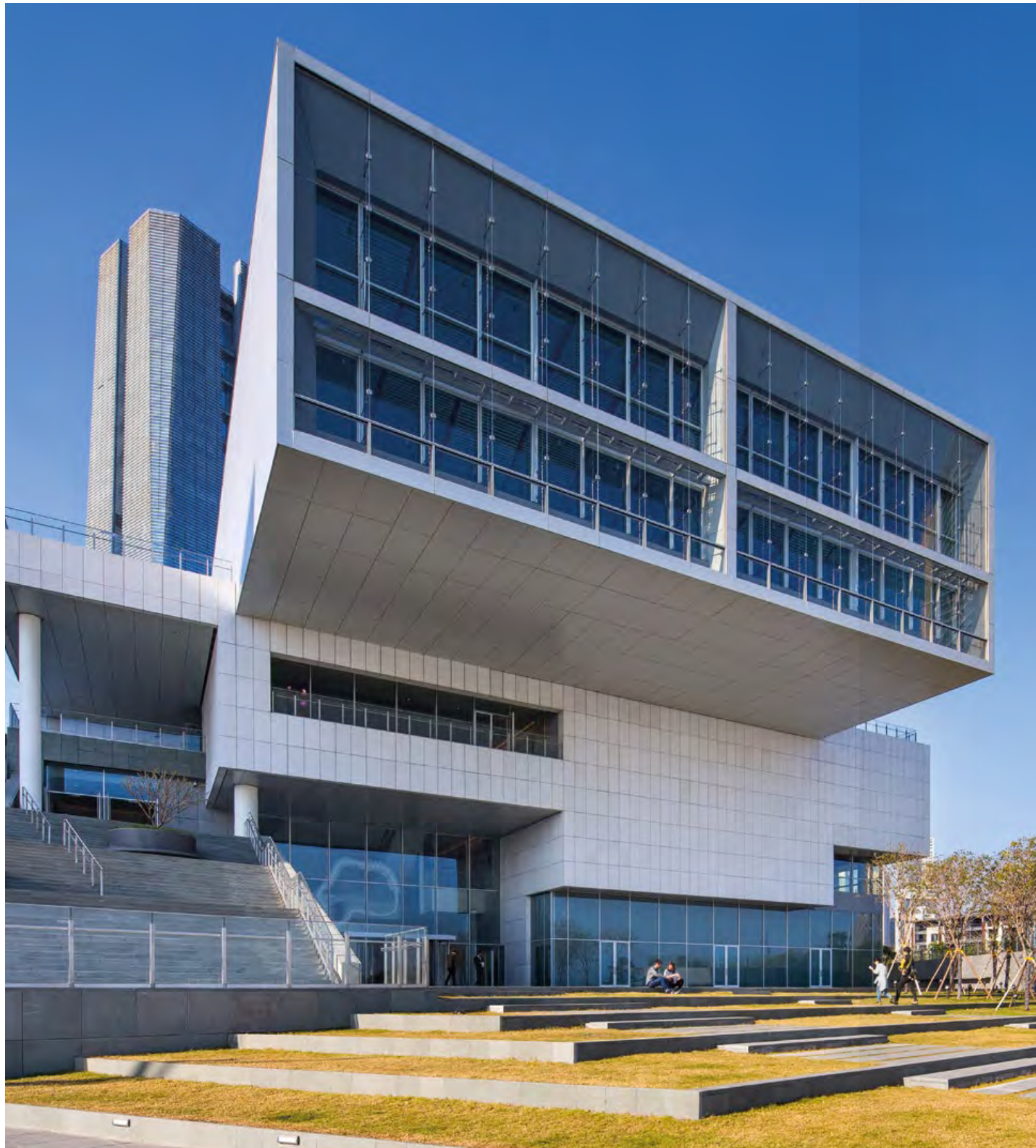
This year, Hong Kong celebrated the long-awaited inauguration of two giant transport links, strengthening its connections to mainland China.

The 55 km Hong Kong-Zhuhai-Macau Bridge, the world's longest sea crossing, shortens travel time from Hong Kong to Macau/ Zhuhai from an hour on a ferry to a 30-minute car ride. Arup provided an array of services for this mega bridge and associated works. These ranged from the concept and reference design for the Main Bridge, to environmentally friendly reclamation solutions and construction supervision for the Hong Kong Boundary Crossing Facilities' artificial island, plus the concept and reference design, tender, and construction supervision of the Hong Kong Link Road.

Our work also included the feasibility study and detailed design for the Tuen Mun-Chek Lap Kok Link Northern Tunnel and Southern Connection Viaducts, preliminary and detailed design for the Macau Link Road, and the infrastructure of the Macau Boundary Crossing.

Equally strategic is the 26 km-long Hong Kong section of the *Guangzhou-Shenzhen-Hong Kong Express Rail Link* which runs mostly underground from downtown West Kowloon to the Shenzhen-Hong Kong boundary, plugging the city into the country's still expanding high-speed rail grid. We were commissioned to carry out the feasibility study, the preliminary design of the tunnels, and the detailed design of the 12 km northern section.

The new bridge and high-speed rail link will further improve transport connectivity between Hong Kong and the major cities in Guangdong province. Together, they are driving the economic and social integration of the Greater Bay Area – and realising the Chinese government's national strategy to create a world-class city cluster to lead the country's future development.



REALISING CULTURAL AMBITIONS

From a population of under 30,000 in 1980 to 12 million today, no city has undergone a greater transformation over the past 40 years than Shenzhen. Now one of China's richest cities, it is a tech hub, a centre of manufacturing, and increasingly, a global cultural destination.

The Sea World Culture & Arts Centre embodies this. Spanning 71,000 m², the six-storey structure houses the Design Society, China's first dedicated cultural design hub, which will soon contain a permanent exhibition space curated by London's Victoria and Albert Museum (V&A).

Arup worked in collaboration with Japanese architect Fumihiko Maki on the project providing structural, façade, security and building physics services that drew on expertise from our offices in Tokyo, Hong Kong, Shenzhen, and London. The result is a destination building and another step towards realising the city's ambitions to become a global leader in the field of design.

◀
SEA WORLD CULTURE & ARTS CENTRE
Shenzhen, China

ENSURING ACCESS TO CLEAN WATER

With a population rising by 3.5% every year, Hanoi is one of East Asia's fastest growing cities. It is expected to be home to nine million people by 2030.

Keeping this expanding population supplied with safe drinking water is a critical issue – not least because a million people a day currently rely on groundwater sources that are over-extracted and increasingly polluted.

To address this problem, our water experts are working on one of the city's largest ever *Water Infrastructure* projects. It will see the construction of a major new surface water treatment plant capable of extracting and processing 300,000 m³ per day from the Hong River – that's the equivalent of 120 Olympic-size swimming pools. The project also includes 18 km of large diameter transmission mains that will connect to the city's drinking water distribution network.

As the technical advisor and tender procurement manager, we are helping the client to overcome numerous challenges. These include working during monsoon season, as well as across a range of manmade and natural obstacles such as the city's key flood protection dykes, rivers, paddy fields, and highways. In doing so, we are helping to provide one million more people with access to clean, safe water.



BEIJING DAXING INTERNATIONAL AIRPORT

Beijing, China

The airport's continuously flowing shape is supported by giant C-shape columns that seamlessly connect with the roof curvature.

OPTIMISING THE WORLD'S LARGEST TERMINAL

The sheer scale of the new *Beijing Daxing International Airport* is almost impossible to fully comprehend without stepping inside. With a floor area greater than 100 football pitches, once open it will become the largest airport terminal in the world.

The building's roof is equally huge. Approximately 1,000m long in both directions, it contains more than 170,000 steel members. Working in partnership with Zaha Hadid Architects and the Beijing Local Design Institute (LDI), Arup's role was to make the construction of this massive, complex structure a practical, affordable reality.

With our extensive experience in long-span steel structures and cutting-edge structural optimisation tools, we were able to propose comprehensive strategies to enhance the roof design. These included improved truss patterns and a minimised depth for structural members, the combination of which created significant savings in materials, costs, and carbon emissions.

Beyond structural engineering capabilities, our integrated expertise in fire engineering, passenger flow consultancy, and sustainability design is further enhancing the quality of a ground-breaking project that will accommodate 72 million passengers a year by 2025.





@X_EIHKCAJJ · 2018

Awesome experience ☺ in Starbucks Reserve Roastery Shanghai 🙌

DEVELOPING A NEW BRAND EXPERIENCE

The world of high street coffee retail is fiercely competitive, with even the biggest players needing to continuously innovate. Take Starbucks. In recent years, they have opened large-scale *Starbucks Reserve Roasteries* in locations around the world.

Targeted at coffee connoisseurs, each store aims to be as rich and immersive as possible – both physically and digitally. Visitors can watch beans being freshly roasted, then see them funnelled above their heads through a series of pneumatic tubes. Meanwhile, those wanting to unlock added insight can connect to an augmented reality (AR) app that allows them to scan and view information about the roasting process.

Arup's expertise has made this innovation possible. From enhanced electrical infrastructure that supports the AR experience, to detailed fire safety engineering that ensures the various roasting facilities meet stringent standards, we've partnered with Starbucks to overcome every issue, in every location – building a genuinely global partnership with a genuinely global brand.

OPENING UP A HONG KONG LANDMARK

Tai Kwun Centre for Heritage and Arts is Hong Kong's largest ever historic building revitalisation project, transforming the city's former Central Police Station compound, with its 170 years of history, into a new arts and cultural centre. Having been open for just five months, it has already welcomed more than one million visitors.

Tai Kwun, or 'Big Station', is the colloquial name of the compound. Now open to the public, the Centre provides a rare 'courtyard' in one of the world's most densely populated cities. Here, people can contemplate the scenery, the city's heritage, and the world's contemporary arts.

Behind the scenes every aspect has been considered – from the adaptive reuse of materials to innovative foundation solutions that minimise impact on the historic buildings. Arup has been involved in the project since 2007, providing multidisciplinary solutions covering structural, civil, and geotechnical engineering as well as façade, lighting, fire, materials, and security consultancy. Although mostly invisible, we have played a crucial role in realising this unique space that connects the old and the new, a place that people love.

STARBUCKS RESERVE ROASTERIES

Shanghai, China

In 2014 Arup provided comprehensive engineering services for the first Reserve Roastery in Starbucks' home city of Seattle. This year has seen us provide similar partnering services for a new 2,700m² store in Shanghai, with further collaborations in progress in New York, Milan, Tokyo, and Chicago.

In Europe our featured projects span Turkey, Denmark, Italy, Ireland, the North Sea, and Spain. From giving derelict buildings a second life to regenerating forgotten neighbourhoods, we continue to shape and reshape the continent's cities – making them better places to live, work, and play.



BLOX

Copenhagen, Denmark

BLOX is a new, six-storey mixed-use development that allows everyone in Copenhagen to enjoy better access to the waterfront.

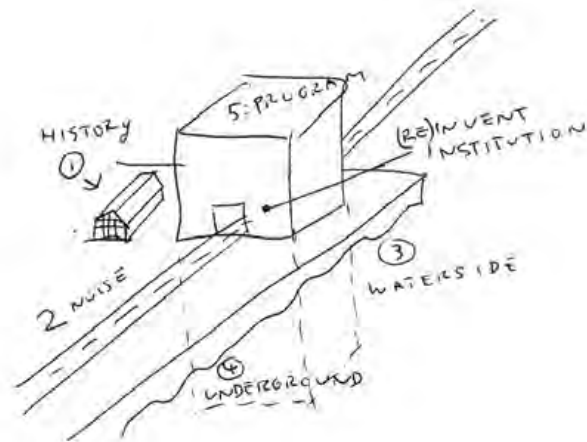
RECONNECTING A CITY WITH ITS HARBOUR

Opened in May by the Queen of Denmark, *BLOX* is an audacious example of how a derelict urban site can be imaginatively revitalised. The new home of the Danish Architectural Centre, the stack of cubes that make up *BLOX* also contains an auditorium, offices, exhibition space, a museum, and residential apartments. An automated, 350-vehicle car stacker is housed in the basement.

Collaborating with architects OMA, our engineers overcame constraints which had hampered development of the site for six decades. These included building in close proximity to the harbour and Frederiksholms Kanal, and constructing under and over the Christians Brygge ring road. By spanning this highway, *BLOX* now allows pedestrians to walk to the water's edge without having to cross a road used by more than 25,000 cars a day.

Denmark's climate provided another challenge. Detailed thermal analysis helped us design a naturally ventilated, highly insulated façade. Meanwhile, the potential movement and separation of the complex's interfaces was resolved by our structural and fire engineers.

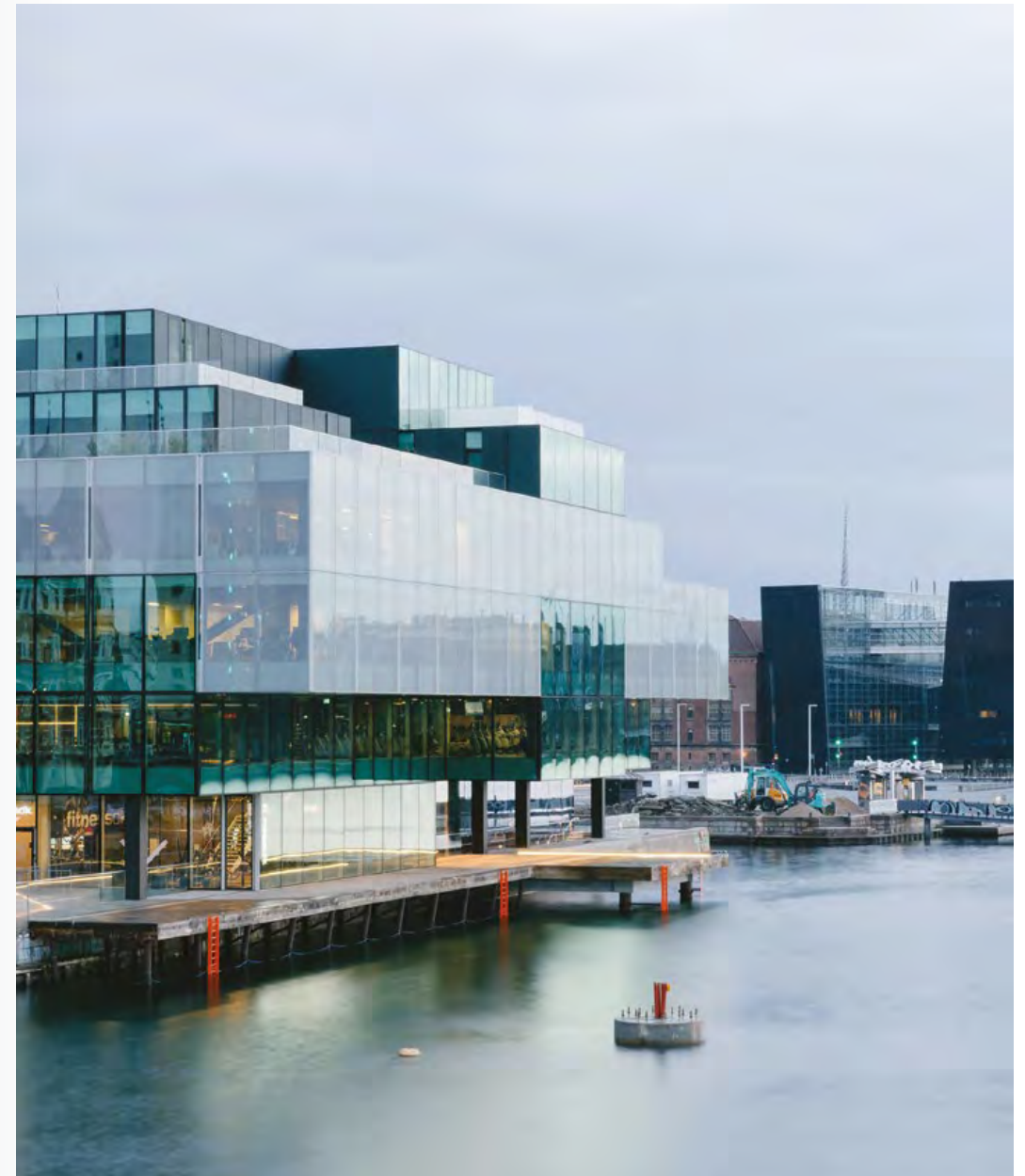
A landmark structure spread over six storeys, *BLOX* has created a new destination in Copenhagen – and reconnected the city with its harbour.



BLOX

Copenhagen, Denmark

Spanning the Christians Brygge ring road, *BLOX* provides pedestrians with multiple routes to the harbour without crossing the road.



BLOX

Copenhagen, Denmark

Arup's structural design encompassed a new urban playground which offers a safe space for play during the day and transforms to a stage or amphitheatre seating in the evening.



DECOMMISSIONING FOSSIL FUEL FACILITIES

For more than 20 years, our focus in the energy sector has been on sustainability. Renewable energy is a huge part of this but we have also developed expertise in safely dismantling redundant fossil fuel facilities. Two examples in Ireland and the North Sea show the positive benefits our skills here can bring.

The *Kinsale Gas Fields* have played a crucial role in supplying Ireland with natural gas since 1978. They will come to the end of their productive life by 2020 and complex work is required to ensure the production facilities are safely decommissioned.

Specifically, the Kinsale gas wells need to be permanently plugged and facilities including two 13,000-tonne offshore platforms and 150 km of subsea pipelines must be sustainably decommissioned. The majority of these sit more than 90 m below the surface.

Arup is providing technical expertise to underpin this complex task. From planning and regulatory consents to environmental impact assessments and broader engineering advice, our expertise is key to ensuring all facilities are decommissioned as efficiently and effectively as possible.

In the North Sea our work with the Brent Field decommissioning project was equally important and even more dramatic.

In just 10 seconds, the topside of Shell's 24,200-tonne *Brent Delta Oil and Gas Platform* was lifted clear from its concrete base by the world's largest vessel – Allseas' *Pioneering Spirit*. While swift, this record-breaking lift was the culmination of years of planning, engineering design and structural work to the platforms.

This was the first major decommissioning project of its kind in the North Sea, where the topside of such a large platform was removed in one piece to be dismantled and recycled onshore.

Working alongside Shell and Allseas, we supported the decommissioning of the platform by designing the strengthening required to enable cutting the Delta's three supporting concrete legs, to allow the separation of the topside from its supporting base. This made it possible for the legs to be cut and the platform de-manned several months before the topside removal, reducing health and safety exposure.

Following the success of the Delta topside single lift, our team is now working with Shell and Allseas on the preparation for the Brent Bravo topside lift.



BRENT DELTA PLATFORM

North Sea

The platform topsides sat on a three-legged gravity based structure, 185 km north-east of Shetland.



COMBINING DIGITAL AND STONE

Antoni Gaudí's *La Sagrada Família Church* is finally due for completion in 2026, a century after his death. Gaudí's singular vision has been an adventure in structural design and construction technology ever since he began the project in 1883.

In 2014, the Sagrada Família Foundation approached Arup to help with the remaining structural design, particularly the final six towers dedicated to the Four Evangelists, the Mother of God, and Jesus Christ.

Aware that towers built in traditional masonry would be too heavy for the crypt and foundations below, our design uses pre-stressed stone masonry as the primary structural element. Half the weight and fabricated remotely using laser-cut templates, each piece is modelled in 3D and designed to slot into place like a giant LEGO brick. Installing a 5 m tall and 4 m wide panel now takes just half an hour, saving time and enabling a safer construction process.

Our work on the Sagrada Família combines deep human knowledge with powerful algorithmic tools. This human-plus-digital approach is helping us bring Gaudí's otherworldly vision to life within a realistic timeframe.

“The work of the Arup team has allowed us to build the central towers with the innovative technique of pre-stressed stone. We value their rigour and the research for the most effective, clear and simple solutions.”

Jordi Faulí
Architectural Director, Sagrada Família Foundation



▲ SAGRADA FAMILIA Barcelona, Spain

Our pre-stressed stone panel method echoes the pure masonry construction used in the earlier construction of Sagrada, while the more modern off-site manufacturing approach guarantees consistently high quality.

PLANNING BEYOND THE TERMINAL

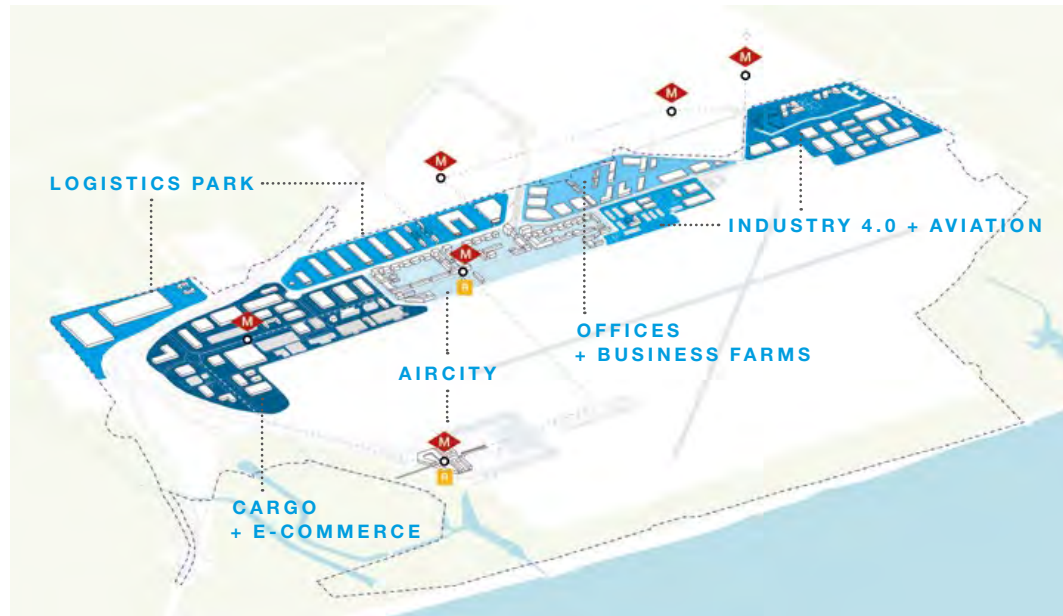
From celebrating Barcelona's history to shaping its future, this year we continued our work with leading airport operator Aena on the *Barcelona-El Prat Airport Master Plan*. As well as developing the overarching vision, Arup is the design lead, providing strategic advisory, urban, airport and economic planning, infrastructure, and transport consultancy services.

As with all our airline master planning work, we are helping the client look beyond the terminal to the wider business and cultural opportunities the new development can bring. The 328-hectare masterplan seeks to spark local economic activity by reinventing the relationship between Barcelona and its airport, which will become a centre for digital commerce and economic growth.

Designed to maximise the business opportunities of the digital age, the airport will contain a cutting-edge e-commerce hub. Here, cargo will be handled and distributed using automation and robotics.

Air City is another feature. Fully integrated with the terminal, this mixed-use development will significantly extend the airport's commercial space, retail opportunities and hotel facilities.

This is just the start of a 20-year scheme destined to become the largest urban development project in Europe. It's a bold plan which repositions the airport as a 'European centre of business' while providing 47 million passengers annually with a world-class travel experience.



KOCAELI METRO
Kocaeli, Turkey
A new Driverless Metro Line



1.8m

Over 1.8 million square metres of mixed-use development

€1.28bn

Of total investment

AUTOMATING A CITY'S TRANSPORT LINKS

In Turkey, the industrial city of Kocaeli is embracing the latest in public transport innovation. A new 15.6 km, *Driverless Metro Line* will link the city's main districts of Gebze and Darica – improving connections to one of Turkey's biggest and fastest growing industrial zones.

Arup has been involved from the outset, providing preliminary and reference designs, and tender documentation. We were also responsible for determining the locations of the stations and route, the operating scenarios, the design

of the line and depot area, and the financial and economic feasibility studies. Made more complex by hilly terrain, this project combines our rail, infrastructure, geotechnical, tunnel, architectural, structural, mechanical, electrical, and ICT expertise.

The new metro line continues our connection with the city. We have previously provided an engineering study for 34 km of Izmit's light rail transit system and completed a master plan for its interchange system.

15.6 km

A new 15.6 km driverless metro will improve connections in a rapidly developing city

BREAKING DOWN TOLL BARRIERS

Eflow is a barrier-free electronic tolling system that allows traffic to move freely on Dublin's orbital motorway – a strategic artery in Ireland's road network.

In outsourcing the operation of this system to private sector operator Emovis, Transport Infrastructure Ireland (TII) has assigned responsibility for managing over one million customers and annual revenue of more than €140m. This is a significant proportion of the budget for maintaining the national road network.

TII has entrusted Arup with overseeing and guiding the operation, making sure that their reputation and revenue is secure. Our work also entails applying best practice in outsourced customer service provision and digital technology to the benefit of Dublin's road users.

LIGHTING UP KEMERALTI

Extending the usability of public space from day into night-time was the key driving force behind the *Lighting Masterplan* for the historical Kemeralti area in the port city of Izmir. The aspiration for Turkey's third largest city, crossroads of cultures on the Aegean Sea, was to create a lighting identity for its lively historic district – introducing a sustainable, integrated lighting system that would help to highlight its cosmopolitan heritage and improve visitor experience.

Arup's lighting designers and electrical engineers were appointed to create a lighting masterplan for Kemeralti District, together with the concept, schematic, and detailed design of green areas, local streets, and squares.

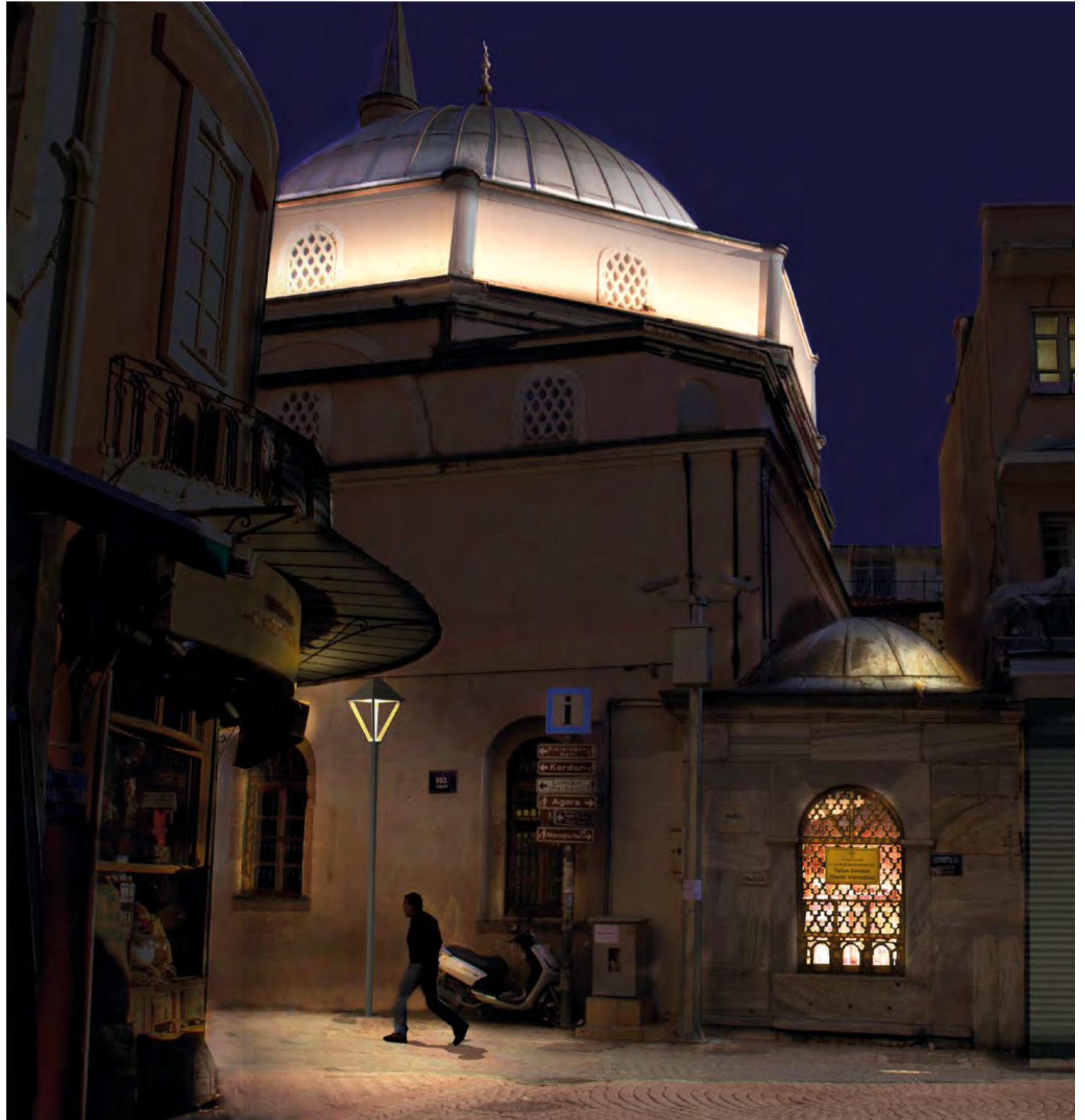
Our proposed lighting masterplan is part of the Izmir Tarih Project, which promotes a socially integrated development of the district. Our plan features sustainable lighting design solutions and state-of-the-art electrical engineering to illuminate the ancient, multi-layered character of the area.

By creating well-lit, safer urban nightscapes, public spaces like streets and squares acquire an even more prominent role in the social and economic life of the local community, particularly in temperate climates, promoting commerce, and encouraging more diverse social use of the spaces.

50%

Total energy savings under proposed intervention

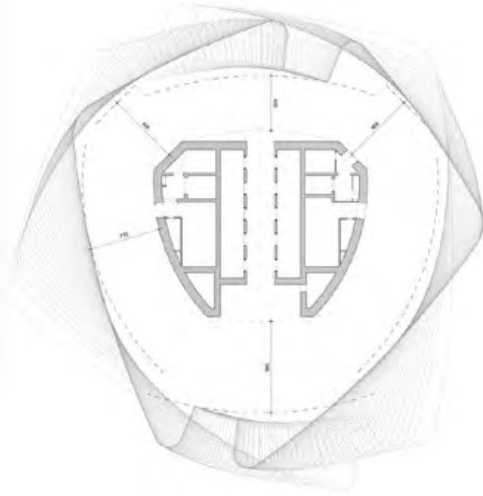
▶
**KEMERALTI LIGHTING
MASTERPLAN**
Kemeralti, Turkey





@ILMILANESEABELLITO · 2018

To raise the eyes to the sky at @citylifemilano means to see wonders



GENERALI TOWER

Milan, Italy

The Tower is 177 m high, with approximately 40,500 m² of cladding surface area, comprised of six different cladding types.

PUTTING A NEW TWIST ON FAÇADE DESIGN

CityLife is a €2 billion residential, commercial, and business district under development in Milan's old city. Central to the development are three skyscrapers designed with Arata Isozaki, Zaha Hadid, and Daniel Libeskind. Arup has worked on all three towers, with our collaboration with Zaha Hadid Architects on the *Generali Tower* presenting some particularly interesting challenges.

With a design defined by algorithms, each of its 44 floors has a slightly different relationship with the floors above and below. This allows the tower to twist up out of the landscape and provide users with a constantly changing view of the Alps and the surrounding city as they move up the building.

A critical feature of this striking new building is its double skin façade, designed by our specialist teams in Milan, Dublin, and London. Their expertise allowed the ambitious design to become a practical reality, with 40,500 m² of cladding elegantly flowing around the building's helical twisting form.

Technically exacting, the façade is essential to the building's bold aesthetic – but its benefits are more than merely decorative. The double skin of sun-deflecting louvers, flanked by glazing, provides efficient thermal control and energy performance on every floor. This has played a big part in the tower receiving a LEED (Leaders in Energy and Environmental Design) Platinum Award – clearly demonstrating that world-class façade engineering can result in buildings that are as practical as they are beautiful.



Better connected cities, cleaner energy and roads optimised by artificial intelligence, our featured work in the United Kingdom this year focuses on improving the everyday lives of people – both today and in generations to come.

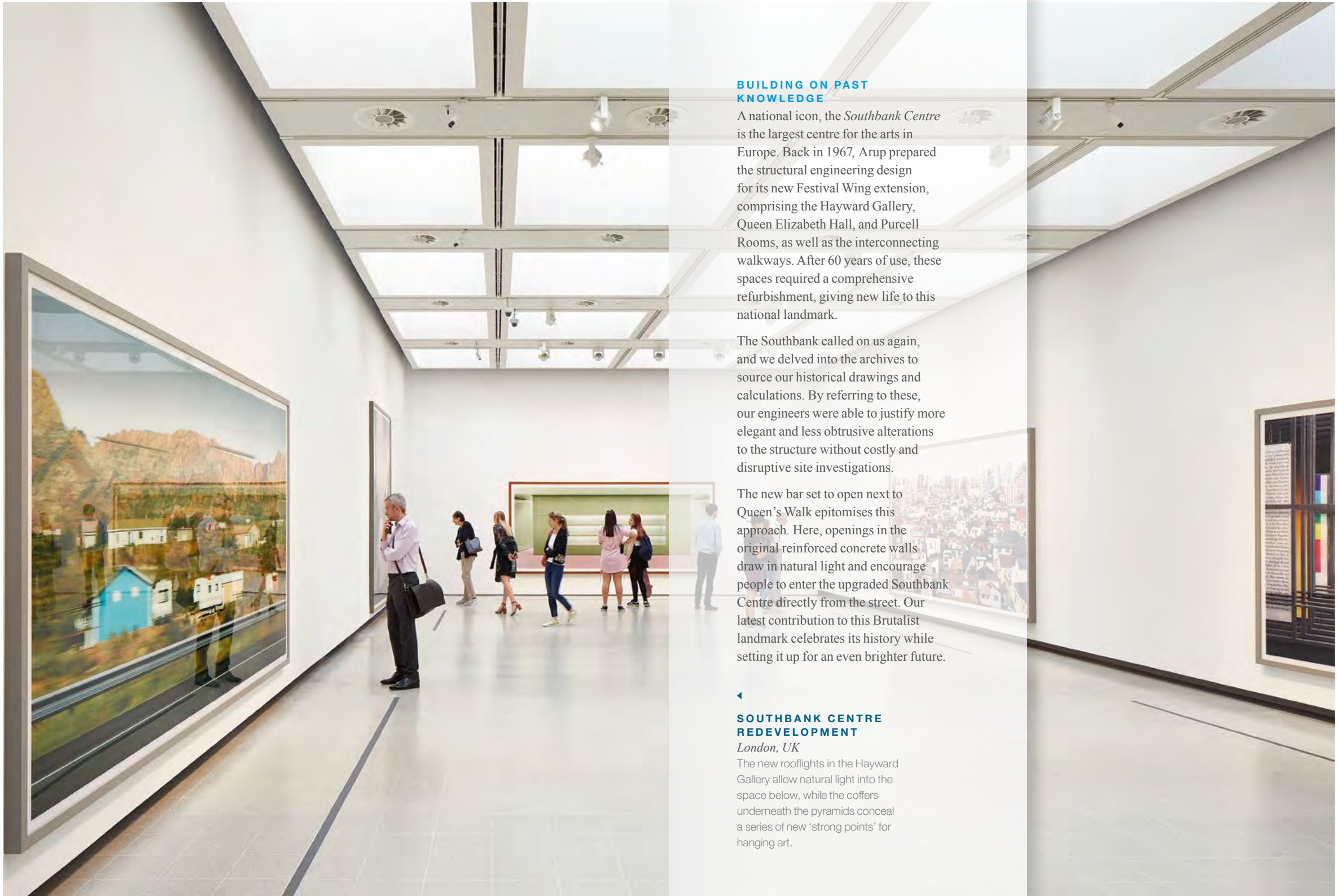


**SOUTHBANK CENTRE
REDEVELOPMENT**

London, UK

New pyramid rooflights above the Southbank's Hayward Gallery have allowed sculptor Henry Moore's original vision for the Gallery to become a practical reality.





BUILDING ON PAST KNOWLEDGE

A national icon, the *Southbank Centre* is the largest centre for the arts in Europe. Back in 1967, Arup prepared the structural engineering design for its new Festival Wing extension, comprising the Hayward Gallery, Queen Elizabeth Hall, and Purcell Rooms, as well as the interconnecting walkways. After 60 years of use, these spaces required a comprehensive refurbishment, giving new life to this national landmark.

The Southbank called on us again, and we delved into the archives to source our historical drawings and calculations. By referring to these, our engineers were able to justify more elegant and less obtrusive alterations to the structure without costly and disruptive site investigations.

The new bar set to open next to Queen's Walk epitomises this approach. Here, openings in the original reinforced concrete walls draw in natural light and encourage people to enter the upgraded Southbank Centre directly from the street. Our latest contribution to this Brutalist landmark celebrates its history while setting it up for an even brighter future.



SOUTHBANK CENTRE REDEVELOPMENT

London, UK

The new rooflights in the Hayward Gallery allow natural light into the space below, while the coffers underneath the pyramids conceal a series of new 'strong points' for hanging art.



CONNECTING THE NORTH OF ENGLAND

The *Transpennine Route Upgrade* aims to deliver faster, longer, more frequent, and more reliable rail services across the north of England, from Newcastle, Hull, and York towards Manchester and Liverpool via Leeds. As part of the Great North Rail Project, the aim is to stimulate economic growth through better connections between towns and cities.

Arup, in an alliance with Amey and BAM Nuttall, was appointed by Network Rail to work on the rail upgrade programme between the cities of Manchester and Leeds. We are jointly designing potential infrastructure options covering the railway systems upgrades to track,

train control, electrification, civil structures, and stations.

In December 2017, potential infrastructure options were submitted to the Department for Transport (DfT) for consideration. A significant investment in a programme of route upgrades is expected to begin in spring 2019.

“This is not just about meeting rising demand for train travel. It’s about transforming journeys too.”

Rt Hon Chris Grayling
Minister for Transport

PROTECTING A CITY FROM FLOODING

The first phase of the *Leeds Flood Alleviation Scheme* has been constructed to protect central parts of Leeds against flooding from the River Aire.

Tackling floods takes collaboration. Before our involvement, the favoured solution was to build high flood walls around the river, effectively encasing the area in concrete. While this would have reduced the risk of flooding to the surrounding areas, it would also have restricted access and enjoyment of the riverside, and been visually intrusive. We worked closely with Leeds City Council, the Environment Agency, Yorkshire Water Services and the Canal and River Trust on the project. Together with Dyrhoff, Mott MacDonald, contractor BAM, and other suppliers we have designed a solution that offers robust protection without compromising the character and ecosystem of the waterfront.

Our scheme maintains the connection between river and city. First, we removed two major navigation weirs at Knostrop and Crown Point.

These were then replaced with the UK’s first moving weirs. In normal conditions, the new weirs will be raised to allow barges to navigate the river and to protect city views. At times of high water, they will be progressively lowered to reduce river levels – and the risk of flooding. Our solutions have created flood defences that are subtle and less than 1.2 m high. These provide critical protection for the city, whilst also allowing for enhanced conservation of the local natural environment. Alongside greater scope for leisure facilities and open spaces, the scheme has resulted in a sustainable environment everyone can enjoy.

Landscaped flood defences and modifications to existing buildings were built to achieve the appropriate standard of flood protection. Phase two of the scheme is scheduled to begin in 2019 and will include the planting of two million trees in the upstream catchment to reduce rainwater run-off.

LEEDS FLOOD ALLEVIATION SCHEME

Leeds, UK

The Flood Alleviation Scheme will protect parts of the city against the types of floods caused by Storm Eva in 2015. That storm damaged 3,300 properties in Leeds with an estimated direct damages cost of £40m.

10 km

The length of waterfront protected

3,500

Homes and commercial premises protected



CREATING A NEW CULTURAL SPACE

The *V&A Museum* is one of London's great cultural destinations, with ambitions to become even better. This year saw us leading the complex and innovative engineering work required to redevelop its Exhibition Road Quarter. This £54.5m project includes the Blavatnik Hall – a new, more welcoming entrance, the world's first all-porcelain public courtyard, and the new Sainsbury Gallery – 1,100 m² of column-free space, creating one of the largest temporary exhibition galleries in Europe.

Repurposing back-of-house areas of the V&A into new, beautiful public spaces was a complex task, with a constrained site surrounded by three listed buildings. Creating the Blavatnik Hall and the entrance staircase to the Sainsbury Gallery through and under the listed Western Range Building required an ambitious feat of engineering. The structure, services, and circulation had to weave through this area where the old and the new intersect, as well as providing daylighting and views through large skylights.

Our structural engineering design balances pragmatism with the use of complex analysis. The Arup team collaborated with architects AL_A to optimise the geometry and weight of the folded plate roof, while 3D analysis was used to predict building movements during excavation.

Finally, we were also eager to ensure that the building set benchmarks for sustainability as well as culture. Capitalising on the thermal mass of the basement to reduce heat transfer, we delivered carbon emission savings 25% beyond Building Regulation requirements, alongside a stable internal environment that's critical for a world-class museum.



@SKETCHTHEVIBE · 2018
Lovely bit of design @vamuseum

V&A EXHIBITION ROAD QUARTER London, UK

Complex and hugely ambitious, this project was made even more challenging by the need for the V&A to remain operational throughout its delivery.

50 m

Of concrete piling used in construction of the basement

6,400 m²

Of extra space for the museum

UPGRADING PASSENGER EXPERIENCES

Airports must continually invest if they are to meet the demands of 21st century passengers. *Heathrow* is a prime example. Arup acts as Programme Director for two of their four key areas of investment: passenger experience and baggage. Since 2014, we have provided an array of building engineering services expertise including mechanical, electrical, lighting, acoustics, geotechnic, security, and transport related solutions, together with strategic, technical, and operational advice on over 150 projects in these areas.

Our recent passenger experience work at Heathrow spans every terminal. In Terminal 3, we helped create a new transfer facility which caters for over five million passengers each year. In Terminal 4, we helped reduce queuing times by increasing surge capacity by 20%. Meanwhile, in Terminal 5, our wayfinding experts helped devise more efficient routes to all levels.

Recently, our digital and operational expertise helped Heathrow set new standards and achieve record performance in baggage handling. Having created a single operational model of the airport's existing process, we combined this with new information architecture to identify opportunities for streamlining and analysing baggage performance. We have also supported the health, safety, and wellbeing initiatives within the baggage team, for example assisting with the roll out of new manual handling equipment for baggage handling staff.

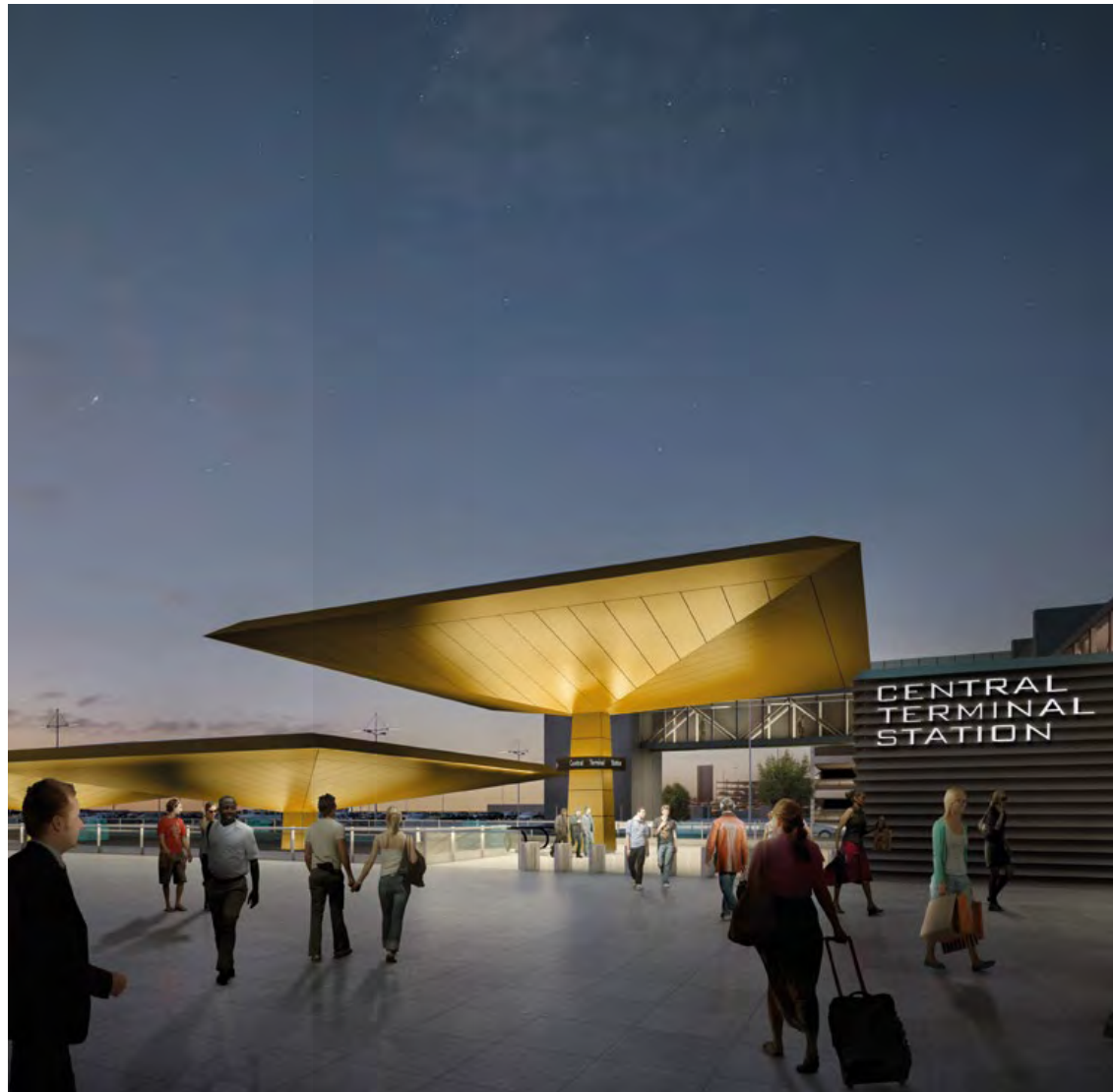
The result is an improved experience for both staff and also the 78 million passengers who pass through the airport each year – a lower percentage of whom now suffer lost baggage.

Arup is also a long-standing technical advisor to *London Luton Airport*. Currently experiencing success with a 50% increase in passengers since 2014, the airport's owners are seeking to upgrade their transport links from train station to terminal. Passengers are currently served by shuttle buses. Queues are frequent and the 2 km journey takes 10 minutes.

To remedy this, the airport is investing £225m in a fully automated, driverless *Direct Air to Rail Transit (DART)* system. Once complete, it will run 24 hours a day, seven days a week, reducing travel time and frustration.

As well as helping the airport secure planning permission, we developed the concept, produced the design, and procured the construction contract for the DART civil works and transportation system. In parallel to supervising the delivery of the DART project, Arup is also the technical advisor supporting the London Luton Airport expansion over the next decade.

The DART system is scheduled to open in 2021. By this time, London Luton Airport is expected to serve 18 million passengers – all with a significantly improved travel experience.



3 minutes

The journey time from station to terminal

4 minutes

The maximum wait for a DART train

▲ DIRECT AIR TO RAIL TRANSIT (DART)

Luton, UK

This investment will transform the experience of those travelling to the airport by rail, reducing congestion on the roads and increasing Luton's potential for economic and employment growth.

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clear story based on the
benefits for Stonehenge,
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highway and
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soon be restored across
storic landscape.

UPGRADING PASSENGER EXPERIENCES

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The result is an improved experience for both staff and also the 70 million passengers who pass through the airport each year – a lower number of whom now suffer lost baggage.

5,000

Year old monument

2.9 km

The length of the new tunnel

£50m

Forecast savings from the accelerated options phase



STONEHENGE BYPASS

Wiltshire, England

The conceptual design of the tunnel considered many safety, construction, and environmental factors.



- World Heritage Site
- Preferred Route
- Proposed tunnel

REMOVING TRAFFIC FROM THE PICTURE

The A303 Stonehenge Improvement Scheme between Amesbury and Berwick Down sounds like a relatively straight-forward project: upgrade a single-lane road to a 12 km dual carriageway, including a new 2.9 km tunnel.

However, there is a prehistoric twist. The existing road cuts across the 4,500-acre Stonehenge and Avebury World Heritage Site, just 165 metres from the monument itself. Any proposal had to consider the impact on the landmark and needed support from heritage organisations including National Trust, English Heritage, and UNESCO/ICOMOS.

We partnered with Atkins to deliver an options study for Highways England to upgrade this critical section of road, facilitating an ‘expressway’ that unlocks regional investment between London and the South West. The scheme will make journeys quicker and safer, and remove the sight and sound of the A303 from Stonehenge.

Collaboration, lean problem-solving, and an active stakeholder engagement strategy

allowed us to announce the preferred route a year earlier than typical for this phase of project. Meanwhile, our planning team secured buy-in from the diverse set of stakeholders with a clear story based on the practical long-term benefits for Stonehenge, the local community, and the travelling public.

Arup also provided highway and tunnel design for the project, as well as environmental, economic, and geotechnical consultancy. The location of the tunnels and portals was essential, so we led a ground investigation, archaeological field evaluation, and drone survey.

These identified several previously undiscovered archaeological features and influenced our choice of route through the west of the site. With public consultation now complete, construction on the A303 tunnel is expected to begin in 2021. Peace and tranquillity will soon be restored across Stonehenge’s prehistoric landscape.

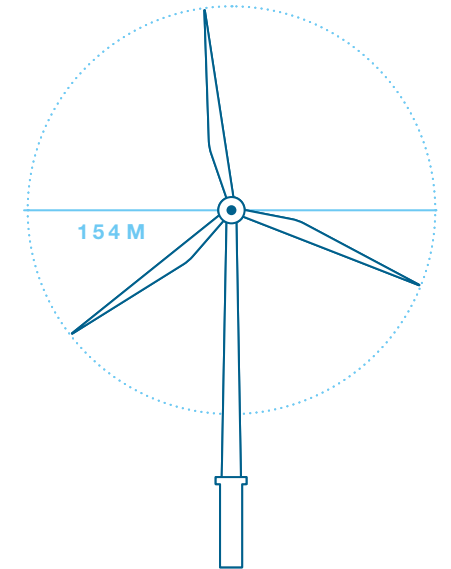


714 MW

Of clean energy will be produced by East Anglia One

2 million

Houses will be powered by the full EA development area



PROPELLING CLEAN ENERGY

East Anglia One is a large offshore wind farm being constructed by ScottishPower Renewables, as part of the wider East Anglia development area. Comprised of 102 wind turbines with a 7 MW generation capacity, it will make a significant contribution to the UK's renewable energy supply for many years to come.

Arup has been working in close collaboration with the client team since 2012, initially to assess and mitigate environmental risks.

Our maritime and ports team have since been working as technical advisers to the client's installation and logistics team. This has seen us helping them with issues across the full span of the £2.6bn project, with a particular focus on procurement risks, supply chain logistics, and detailed assessments

of technical facilities, including the chosen ports of Lowestoft, Great Yarmouth, and Vlissingen.

We have also undertaken key tasks to support the wind farm's on-going operation and maintenance, including the reference design for a three-storey, mixed-use office and warehouse facility, essential to the day-to-day running of EA One and the wider EA development area.

We are continuing to provide a wide range of technical and design advice to ScottishPower Renewables as they complete work on the EA development area. When fully operational this will provide up to two million homes with secure, affordable, low carbon energy – a significant step for the UK energy market.

Ending our journey in the west, our rich and varied work in Canada and the United States has been defined by a pioneering spirit. From beautiful designs that elevate user experiences to bold structures with the power to change lives – it's been another landmark year.



▶ **VAUGHAN METROPOLITAN CENTRE STATION**
Toronto, Canada

This new station is part of the Toronto–York Spadina subway extension, improving connections across the Greater Toronto area.



◀ **YORK UNIVERSITY STATION**

Toronto, Canada
A terraced landscaped light scoop draws daylighting into the concourse below.

▶ **VAUGHAN METROPOLITAN CENTRE STATION**

Toronto, Canada
The curving shell form of the entrance ensures the concourse and platforms are flooded with natural light.

BRIGHTENING COMMUTES IN TORONTO

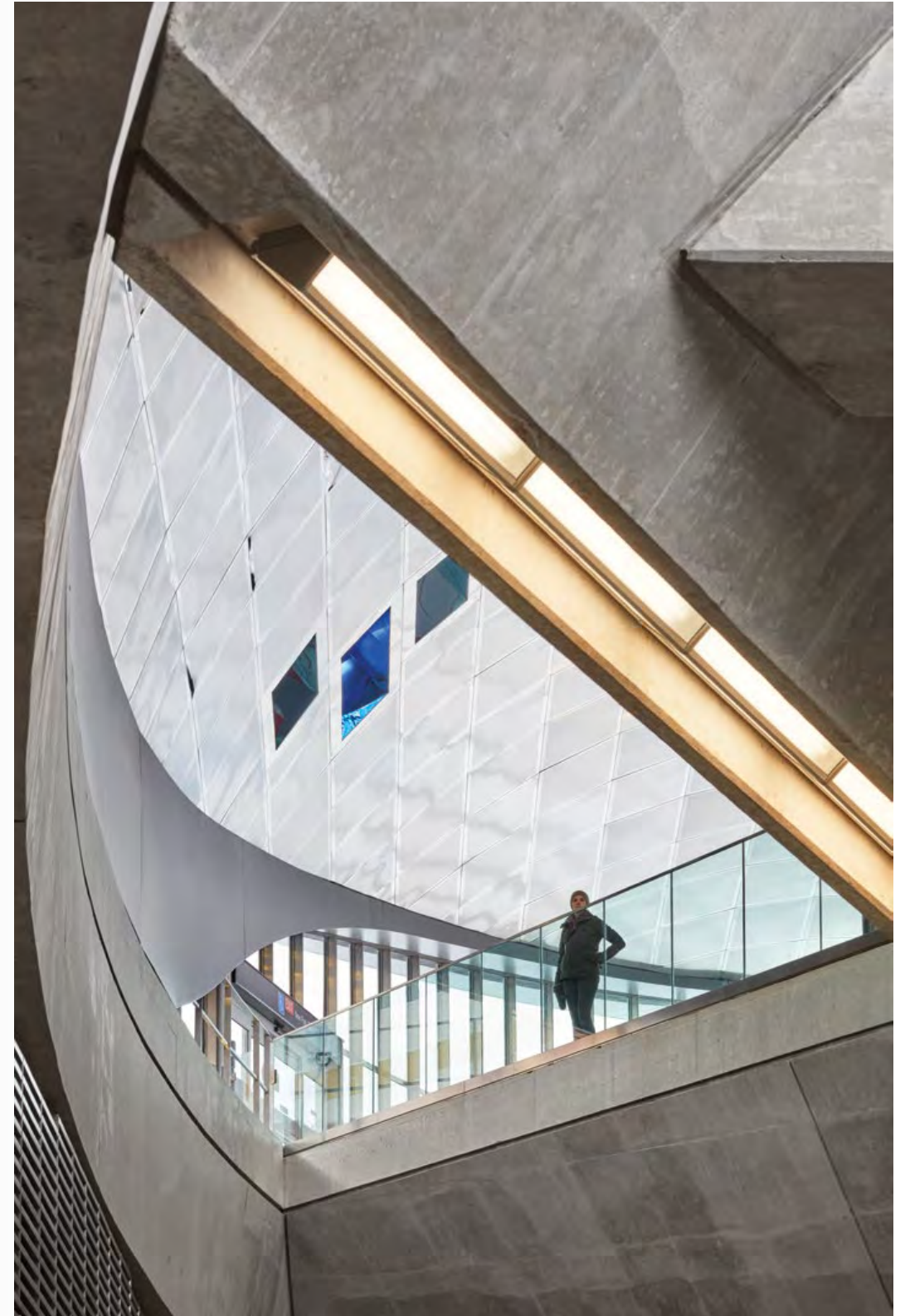
As part of the Toronto-York Spadina Subway Extension, the newly opened *Vaughan Metropolitan Centre (VMC)* and *York University (YU) Stations* will enable direct, rapid access to central Toronto.

Arup served as prime consultant for the two new stations, providing comprehensive, multidisciplinary engineering and consulting services.

VMC Station will help catalyse the growth of a new mixed-use downtown precinct. Its design carefully balances the inspirational with the practical. The curving shell form of the entrance pavilion brings light into the concourse and platforms below, improving users' day-to-day experience. Meanwhile, the station design exceeds Canada's National Energy Code requirements for energy performance by 40%.

A similar balanced ethos also applies at the YU Station. The swooping roof of the entrance provides 40,000 commuters a day with a dramatic focal point, while the station's location at the heart of the University's Keele Campus has reduced bus traffic to and from the university, significantly reducing CO₂ emissions, travel times, and traffic congestion.

Strong collaboration was a key feature of these two landmark stations. Adamson Associates worked with us on both projects, with Grimshaw Architects partnering on VMC, and Foster and Partners on YU.



\$1.86bn

Los Angeles International Airport (LAX) is undertaking a \$1.86bn redevelopment of two terminals

3 nights

Arup orchestrated the relocation of Delta's operation to Terminal 2 and 3 in just three nights

ORCHESTRATING DELTA'S RECORD RELOCATION

Continuing a long-standing relationship with Delta Air Lines, Arup is serving as lead consultant on the *Delta Sky Way* at Los Angeles International Airport (LAX), a \$1.86 billion redevelopment of two terminals at America's second busiest airport.

Once complete, the modern facility will increase screening capacity and gate-area seating as well as providing automated security lanes, a world-class concession programme, and a new Delta Sky Club. This is in addition to the amenities Delta's customers have come to expect at LAX, including the Delta ONE check-in and integrated in-line baggage system.

As lead consultant, Arup is responsible for all design activities on the project, as well as site supervision. A truly collaborative effort, our team includes experts across SMEP, civil, airport planning, façade engineering, sustainability consulting, lighting design, ITC, AV, wayfinding, acoustics, and security.

As a critical link in the global transportation network, LAX must continue to operate at full capacity throughout the demolition, construction, and renovations. It's a similar story for Delta. Seamless operations and a quality experience for the 30,000 passengers they serve at LAX every day can't be sacrificed. To accommodate these needs, we organised the project into phases, starting with the airline's relocation to Terminals 2 and 3.

Arup orchestrated the relocation – the largest of its kind in US history – over the course of three nights. Starting after the last flight left and finishing before the next morning's first arrival, it was completed without incident and without impacting airport operations.



▶ **LOS ANGELES INTERNATIONAL AIRPORT**
Los Angeles, USA



BRIDGING BEAUTY AND FLEXIBILITY

In Montréal, we are advising the Government of Canada as they oversee the replacement of the 3.4 km long *Champlain Bridge* over the St Lawrence River and Seaway and 4km of congested urban highway. One of the busiest transport corridors in Canada, the new bridge is vital to the local and national economy.

Acting as Owner's Engineer, and drawing on our extensive bridge experience, we developed the design and technical requirements for this complex CAN \$4.24bn DBFOM project in parallel – streamlining the procurement process and allowing the Government to meet challenging deadlines.

Our approach carefully balanced visual appeal with future flexibility. The curved alignment and structural pier design created an instantly recognisable shore-to-shore design, while the elegant main tower and its harp of cables add a unique accent.

Looking ahead, the project aims to create a bridge with a lifespan of 125 years. That meant creating a design with a flexible central transit corridor that could house dedicated bus lanes or light rail in the future.

The result is a smart, balanced approach that meets the needs of Montréal today, with the flexibility to accommodate change tomorrow.

▶ **CHAMPLAIN BRIDGE**

Montréal, Canada
The design for the 3.4 km bridge drew on Arup's experience with the Queensferry Crossing in Scotland and the Oresund bridge spanning Sweden and Denmark.

SHOWCASING A COMMITMENT TO INNOVATION

An inspiring facility for research and integrated learning, the *Bloomberg Center* is the first academic building on Cornell Tech's new 12-acre campus on Roosevelt Island, New York. In line with the technology institution's reputation for innovation and progressive ideals, the design and build were underpinned by a net-zero energy focus.

In partnership with Cornell and Morphosis, we pushed the boundaries of active design, creating a low-carbon building which combines hitting ambitious sustainability targets with meeting the functional requirements of an advanced academic facility.

Our net-zero goal influenced every stage of the project. Building loads were analysed thoroughly while allowances for lighting and computers had to be carefully planned. The Center includes a 3,716 m² roof-mounted photovoltaic system. This is part of a campus-wide array of solar panels and ground-source heat pumps. Dedicated to the facility, the pumps harness the constant temperature below ground to both warm and cool the building.

Designed in accordance with the Leadership in Energy and Environmental Design (LEED) 2009 ratings system, the Center is certified LEED Platinum, the highest possible rating. By embracing the net-zero challenge, we have laid down a marker for future development on the campus, helping to regenerate Roosevelt Island.

15,000 m²

The size of the academic facility

3,716 m²

Roof-mounted photovoltaic system



BLOOMBERG CENTER

New York, USA

The Bloomberg Center utilises a rainwater harvesting system that reduces water discharge and potable water usage.



@ZAC_THOMPSON · 2018

Yo that place is mad nice! Roosevelt Island stepped it up 1,000% it's a must see! I told my son he is gonna have 2 go 2 school there.



WEWORK

Global

Unlike typical offices, WeWork caters to multiple ways of working. Its mix of lounge areas, private offices, brainstorming areas, and conference rooms means their spaces see more activity than usual. Taking this into account, Arup performed energy and occupancy surveys to more accurately predict heating, ventilation, air conditioning, and electrical loads.

WORKING BETTER TOGETHER

The way the world works is changing. Shared workspaces which put greater emphasis on community are increasingly prevalent. *WeWork* is leading this change and provides office solutions in 23 countries. Serving everyone from freelancers to large businesses, members can rent anything from a communal desk to a 50-person office.

Arup has worked closely with WeWork for several years, rolling out 50 new co-working spaces across 15 cities in the United States and beyond. Together, we fast-track the creation of uniquely designed spaces – all in WeWork’s industrial-chic aesthetic – capable of hosting a high volume of users. Our scope also includes producing

a design standard for mechanical, electrical, and public health systems.

WeWork is planning considerable expansion. Arup is playing a major role in this growth, particularly through our modelling expertise. All new spaces are now designed in Revit using 3D LIDAR scans of the existing core and shell space, while we also collaborate closely with WeWork’s Building Information Modelling (BIM) team. This, coupled with the standards developed at the outset of each project, enables incredibly fast turnarounds on design and construction. Fitting for a company rapidly changing the way we work.

23

Countries WeWork operates in

50

New WeWork spaces being rolled out across 15 cities

236 miles

Of rail line

300+ km/h

Travel speed

90 minutes

Maximum travel time, reducing commutes by two-thirds



CONNECTING TWO GREAT TEXAN CITIES

The journey between Houston and Dallas takes four to five hours by car or requires a visit to the airport. Soon, the same trip will take 90 minutes or less – thanks to the *Texas Central High-Speed Rail Road (TCRR)*. This state-of-the-art private rail line will connect America's fourth and fifth largest metropolitan areas and represent the first completed high-speed rail line in North America.

Once finished, the TCRR will transport thousands of passengers a day between Dallas and Houston, providing safe and reliable public transportation while spurring economic collaboration between the two cities.

Arup began work on the project in 2013. As Owner's Engineer, we were tasked with identifying flaws preventing system development and drawing up alternative alignments. We continue to serve as a

trusted advisor to the TCRR, leading the conceptual design and providing multidisciplinary services including structural, geotechnical, rail, and civil engineering. Arup also supports the TCRR with planning and management skills to secure regulatory approvals from the Federal Railroad Administration, the U.S. Army Corps of Engineers, the Texas Department of Transportation, and other regulatory bodies.

To minimise environmental impact and reduce costs, we proposed using existing infrastructure as much as possible when selecting potential routes. The rail line will align and interact with existing transportation systems, including highways, railroads and utility corridors. Construction of the TCRR is set to start as early as 2019, with trains slated to begin running by 2025.

SCOTT HALL Pittsburgh, USA

The building's glass façade plays with form, texture, and colour using nanoscience technology developed by NASA in the 1950s.

CREATING A SHIMMERING LANDMARK

Scott Hall is the new Nanoscience, Bioscience and Energy Technologies building at Carnegie Mellon University. It was designed as an inter-disciplinary teaching and research hub for the College of Engineering, with the prestigious Wilton E. Scott Institute for Energy Innovation housed above.

Providing flexible spaces to investigate and collaborate, it's an excellent example of a sustainable laboratory building.

Located on a challenging site, our design team had to be inventive to draw up a beautiful and sustainable building which embraced the local topography. The result of their efforts features two interlocking geometric forms: the North Wing and the Bertucci Nanotechnology Lab, linked together by connecting spaces called the Collaboratory and the Ruge Atrium.

The building includes a dichroic glass façade that combines clear and fritted glazing. Arup worked in collaboration with OFFICE 52 Architecture to create a façade that allows saturated light to diffuse throughout the space. This leads to an ever-changing reflection and refraction that transform the building's appearance throughout the day as light moves through the glass at different angles and intensity. From warm golds to cool blues, the space glows in dynamic ways.

The project's innovations have been widely recognised. Scott Hall received a silver ACEC Award in the 'building and technology systems' category, as well as LEED Gold Certification from the US Green Building Council – one of the first buildings of its kind to earn such certification.

Building on our financial strength

All parts of the firm have contributed to another robust financial performance this year – well aligned to our strategy and plan.

Revenue has grown by 3.6% to £1.56bn, with operating profit, before staff-profit sharing, rising to 12.2%. Profit-sharing distributed to staff, as a percentage of total employment costs, was 8.5%. We have ended the financial year with a healthy forward-order book now standing at £1.31bn, up nearly a quarter from last year. This increase can be attributed in part to our strategic focus on North America, as well as our continued strength in UK infrastructure.

These are healthy results, further strengthening the resilience of the firm for our staff members and our clients.

Looking ahead, we continue to see opportunities in Southeast Asia, China, and North America. We are also mindful of the current political and macro-economic uncertainties in many parts of the world, including the impact of Brexit in Europe. Here, a naturally cautious financial profile, together with our global balance and diversification, holds us in good stead. Increased investment in Digital and Advisory Services also ensures we are well-equipped to deal with the future.

A notable feature this year has been our focus on diversifying our office estate, through a careful balance of acquisitions, disposals, and new leaseholds. In doing so we have maintained our presence in the centre of many of the world’s major cities, staying close to our clients and giving our people high quality spaces to collaborate, innovate, and thrive.

In conclusion, Arup remains a firm operating on resilient financial foundations. Those foundations give ongoing confidence to our clients as they continue to trust in our abilities to address their increasingly complex challenges. They also confirm to our staff that they are part of a firm that is committed to investing in all the resources they need to reach their own potential and produce work of quality for their clients.



MATTHEW TWEEDIE
Group Finance Director

REVENUE (£M)

2014	1,048.3
2015	1,125.5
2016	1,239.9
2017	1,509.5
2018	1,560.0

OPERATING PROFIT (£M)

Before staff profit-sharing

2014	69.4
2015	88.6
2016	125.8
2017	175.0
2018	190.5



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