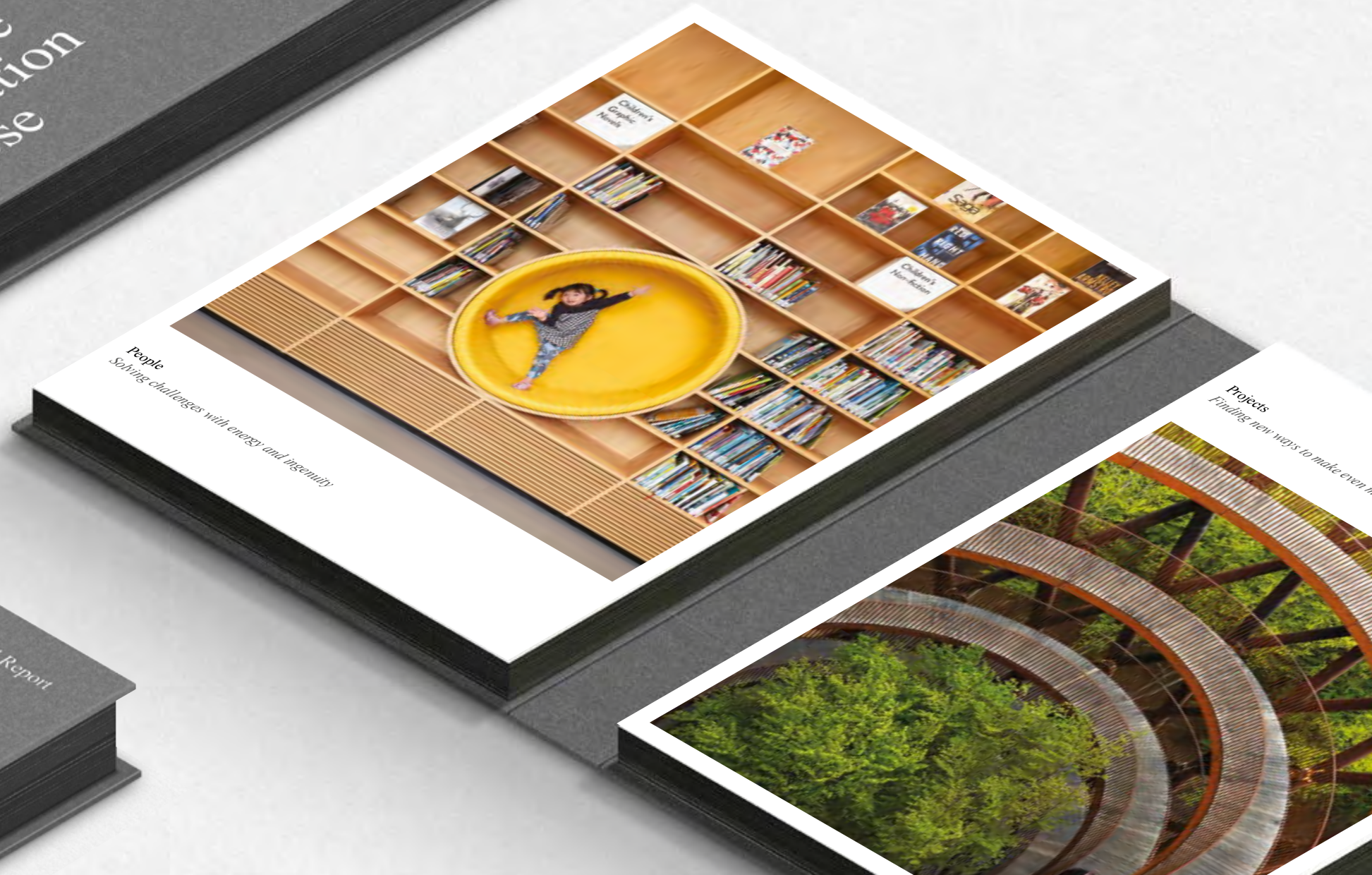


ARUP

Annual Report
2019



ARUP

Annual Report
2019

Excellence
Imagination
Purpose



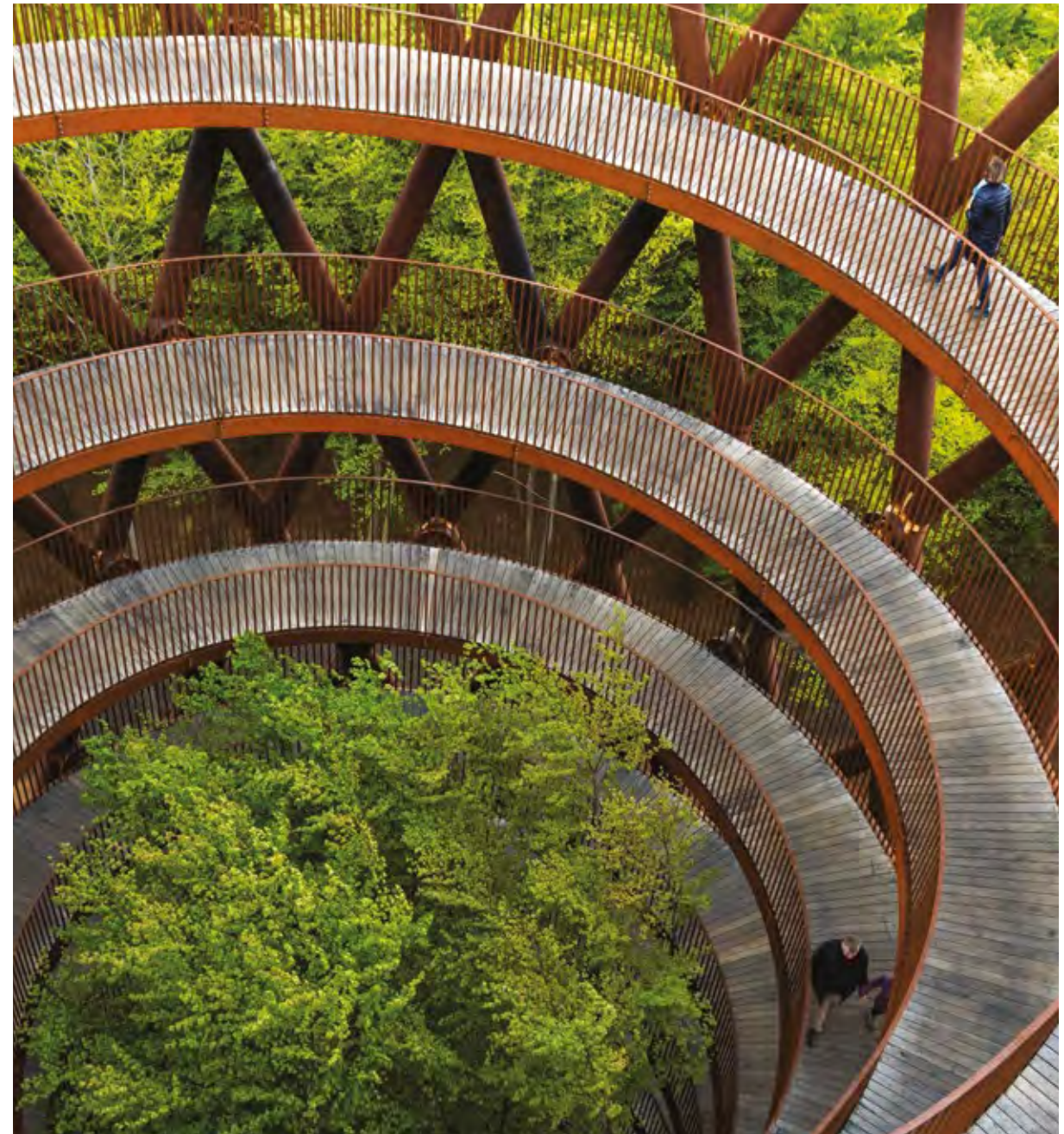
People
Solving challenges with energy and ingenuity

[Read now](#) →

Projects

Finding new ways to make even more of a difference

[Read now](#) →



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This year's Annual Report is told through stories about our people and our projects – connected by the themes of excellence, imagination and purpose.

Half a century on from the direction Sir Ove Arup gave us, the stories about our people demonstrate what his forward-thinking ideas mean for us today. They show how constant innovation fuels imagination and underpins excellence, and the steps we are taking to support and inspire everyone who works with us. They also reflect the central role sustainable development plays in our firm and the focus we place on working with local communities facing difficult challenges.

The project stories show the huge breadth of work we have undertaken for our clients this year – from major cities to rural communities, complex networks to single inspiring experiences. All this work shares a common purpose – the desire to create something of clear value, where our skills help to improve people's daily lives, and support sustainable growth and prosperity.

Highlights

1 APRIL 2018 – 31 MARCH 2019

IN BRIEF

6,931
Clients served

17,138
Fee earning projects

15,870
Members

143
Countries where we have worked

FORWARD ORDER BOOK (£BN)

2017	1.05
2018	1.31
2019	1.36

REVENUE (£BN)

2017	1.51
2018	1.56
2019	1.71

Alan Belfield

Chairman



Arup has continued to create work of real quality and make a positive contribution to communities in every corner of the world, despite these uncertain and turbulent times.

Our financial position remains robust. However, our real strength lies with our members who continue to demonstrate both ingenuity and determination, however big the challenge.

As I begin my time as Chairman, I'm conscious that I am very much a steward. My goal is clear – to ensure that our firm continues to do great work for the benefit of our clients and communities, through a team of talented people who are happy and fulfilled.

In my first days, a summary of recent projects lay on my desk. One page particularly struck me. It showed the awe-inspiring Queensferry Crossing in Scotland alongside the seemingly humble drawings of new hand-washing stations that we designed to improve hygiene in refugee camps around the world. In one respect they couldn't be more different. Viewed another way they are exactly the same – clever solutions to complex problems that are making a real difference to people's daily lives. This is what 'shaping a better world' really means.

SUSTAINABLE DEVELOPMENT

There is no escaping the fact that the global geopolitical situation is volatile and it's getting harder for any business to plan with certainty. Equally, other factors like rapid urbanisation, social inequality, climate change and the constantly expanding impact of new technology are all having a major effect on the clients we work for.

These issues are all related. That's why we took the decision in 2017 to build our response around the United Nations Sustainable Development Goals (SDGs). The comprehensive, action-based nature of these goals aligns with our own values. As advisors, designers and engineers, we see these issues up close, every day. The SDGs offer us a platform to do something substantive across every facet of our operations ([page 36](#)), and they're providing additional impetus to many of the good things our firm has already been doing for some time.

One example is the growth of our water and energy work. This is aligned with the SDGs, whether it has seen us strengthening water resilience in India ([page 122](#)), pioneering the use of hydrogen energy in New Zealand ([page 106](#)) or helping refugee communities in Ethiopia access affordable sustainable energy ([page 45](#)).

We are eager to expand our work in these areas in the years ahead. The world needs new, more sustainable solutions, and the innovative, research-based work we are doing on programmes like City Water Resilience ([page 110](#)) gives us the strength and insights we need to help our clients achieve real change.



▲
MACTAN-CEBU INTERNATIONAL AIRPORT
Lapu-Lapu City, Philippines

GEOGRAPHIC STRENGTH

Against a turbulent global picture, we have again performed well across all our regions and all our markets this year. Revenue has grown by 9.9% to £1.71bn, with an operating profit (before staff profit-sharing) of £135.4m.

We have helped shape a better world in 143 countries this year. And in each of our five regions, we want to be where the challenges are and where there is an opportunity for us to make a difference.

In North America we continue to see an increasing demand for our services in both the USA and Canada. Our work here has been hugely varied, from iconic projects like the redevelopment of Seattle’s Space Needle ([page 100](#)), to our specialist acoustic collaboration with the musician Björk ([page 98](#)).

Personally, I was delighted to be present at the opening of the hugely impressive Champlain Bridge in Montréal. The bridge will be the busiest in Canada with 50 million crossings a year. Canada’s Infrastructure Minister, Francois-Philippe Champagne, provided a sense of its stature for the whole region: “We talk about the Golden Gate Bridge and the Brooklyn Bridge, and I think this will be a historic landmark for Montréal.”

Another area of rapid expansion is South East Asia. We have strengthened and grown our operations in Malaysia and Vietnam this year and expect to continue increasing our presence in Singapore, Thailand, Indonesia and the Philippines. The bold, locally appropriate design of Mactan-Cebu International Airport ([page 80](#)), is a good example of the impact we are making.

EXPANDING IMPACT

For much of our history, design, architecture, planning and engineering has been Arup’s main focus. Over the past decade our advisory services have grown in importance.

These advisory services, anchored in our technical expertise, are now making a real difference to our clients’ businesses. Technical experts are working hand in hand with colleagues skilled in strategy, economics, finance, sustainability, operations and change management. Together, our work allows clients to, for example, understand the viability and potential benefits of proposed schemes, enabling them to invest with greater confidence. It also allows them to improve the development and performance of assets ranging from industrial plants to airports. Our work advising the hugely complex £1bn London Power Tunnels project ([page 104](#)) clearly illustrates the benefits we can bring.

DIGITAL LEADERSHIP

Digital technology, in all its different forms, is another area of significant development. We’re making huge strides forward in the way we collect, manage and use data to inform everything we do. We’re also rapidly expanding our use of automation, machine learning and artificial intelligence to solve new and greater problems.

With our clients, advanced technology is expanding our ambitions and capabilities. Enhanced modelling techniques are making designs for groundbreaking structures like the Forest Tower in Denmark possible ([page 86](#)). Machine learning is helping us implement more effective flood management strategies, with benefits for vulnerable communities around the world ([page 26](#)). Meanwhile, our use of blockchain technology is allowing young homeless people in Berlin to access critical services without the need for bank accounts or credit cards ([page 124](#)).

Getting the most out of digital advances is as much about people as processing power, and our firm-wide digital transformation programme is beginning to pay dividends. The tools our people develop and the data they depend on are being shared in new ways, enabling a greater level of collaboration than ever before.

▼
LONDON POWER TUNNELS
London, UK



MEMBERSHIP MINDSET

Our founder, Sir Ove Arup, often spoke about the importance of people. How people are ‘members’ of organisations they want to be part of. Their participation is voluntary, and a reflection of what Sir Ove called ‘unity and enthusiasm’. Everyone at Arup is always eager to nurture this mindset, ensuring a thriving and collaborative culture for all our members.

As I outlined earlier, we are increasingly welcoming people with a wider range of skills and backgrounds. It also sees us actively celebrating diversity and inclusion. In a traditionally male-dominated profession, we can’t create perfect gender balance overnight. What we can do is make it a constant focus and measure our progress year by year. An improvement of almost 2% towards a better, gender-balanced membership is a step in the right direction this year ([page 31](#)).

Professional development is another important focus. The skills our clients require are changing. We’ve got to provide all our people, at every level of the firm, with the training and education they need to stay relevant in today’s rapidly evolving working environment. Arup University’s Masters Modules are just one example of the approach we are taking – equipping future leaders with knowledge of emerging fields like machine learning and artificial intelligence, or urban resilience.

SPACE NEEDLE RENOVATION

Seattle, USA



FOREST TOWER, CAMP ADVENTURE

Rønnede, Denmark

TELLING ADVICE

In September 2018 we held our Group Annual Meeting in London. We were delighted to be joined by Sir Jack Zunz, a founding father of this firm and a past co-Chairman. Sadly, it was the last time many of us spent time with Sir Jack, as he passed away in December last year, aged 94.

Much as he would have hated the accolade, Sir Jack was a great man. As a structural engineer he led our work on the Sydney Opera House – alongside Sir Ove himself – and shaped a host of landmark projects in London, Hong Kong and South Africa. As a business leader he contributed hugely to the firm we are today, overseeing our expansion into North America, founding the Arup graduate programme and launching the Ove Arup Foundation.

As I look ahead to all the challenges and opportunities we face as a firm, a telling piece of advice Sir Jack shared with us in London continues to resonate with me: “Strive for excellence and behave decently.”

In just six words Sir Jack captured the real essence of Arup. If we follow his advice and harness the ever-expanding talents of everyone in the firm, I’m confident we’ll continue to achieve great things.

ALAN BELFIELD
Chairman

Governance



We believe good and fair-minded governance, together with our independence, creates the conditions for our people to flourish. Our Group Board is central to this approach. They are appointed by the firm's Trustees and set our strategy. The Group Board is responsible for Arup's long-term success, financial security, unity, wellbeing and sustainability.



GROUP BOARD

- | | |
|---|---|
| Fergal Whyte ¹ | Tim Stone ⁹
<i>Non-Executive Director</i> |
| Isabel Deding ³ | Fiona Cousins ¹⁰ |
| Peter Chamley ⁴ | Tristram Carfrae ¹²
<i>Deputy Chairman</i> |
| Jerome Frost ⁵ | Matthew Tweedie ¹³ |
| Paul Coughlan ⁶
<i>COO</i> | Michael Kwok ¹⁴ |
| Dervilla Mitchell ⁷ | Genevieve Shore ¹⁸
<i>Non-Executive Director*</i> |
| Alan Belfield ⁸
<i>Chairman</i> | |

OFFICERS OF THE BOARD

- Clare B Marshall²
- Rob Greig¹¹
- Martin Ansley-Young¹⁵
- Karim Klaus Emara¹⁶
- Jenni Emery¹⁷

*Genevieve Shore stepped down as a Non-Executive Director of the Group Board on 30th June 2019

People awards

Around the world, Arup members continually strive to shape a better world. We're pleased when the quality of their work is recognised. This is a selection of the past year's awards:

Daniel Lambert

Water Professional of the Year (Winner)
New South Wales Water Awards
Australian Water Association

Kaitlin Langdon

Australia's Most Innovative Engineers
– General Industry
Engineers Australia

Daniel Messina

Australia's Most Innovative Engineers
– Manufacturing and Automation
Engineers Australia

Zoe Wilks

Australia's Most Innovative Engineers
– Young Engineers
Engineers Australia

Charles Ormsby

Emerging Engineer of the Year
Association Des Ingénieurs-Conseils
Du Québec

Eoghan Lynch

Outstanding Contribution to Engineering
Award (Winner)
Engineers Ireland Excellence Awards

Mitsutake Tanigawa

13th Japan Structural Design Award (Winner)
For Nicca Innovation Centre, Fukui, Japan
Japan Structural Designers Club

Junichiro Ito

30th Annual Japan Structural Consultants
Association Award

Berlina Winata

Colin Yip

Young Consulting Engineer of
the Year Award (Winner)
Association of Consulting Engineers Singapore

Giuseppe Gaspari

Young Tunneller of the Year
International Tunnelling and Underground
Space Association

Bob Lang

Gold Medal Award (Winner)
Institution of Civil Engineers

Susan Deeny

Karen Burt Memorial Award (Winner)
Women's Engineering Society

Karoline Lende

Graduate of the Year (Winner)
New Civil Engineer Graduate Awards

Darryl How

Yasmin Chamadia

Young Engineers Award (Winner)
Society of Public Health Engineers

Ben Bryden

Apprentice of the Year Award
Infrastructure Strategic Alliance

Áine Ní Bhreasail

Engineers Trust, Young Engineer of the Year
Royal Academy of Engineering

Catherine Wenger

Recognising Women in Engineering
Leadership Award
New Civil Engineer

Tammy Whelan

Daniela Zanni

Lauren McNaughton

Sarah Mulvanny

Top 50 Women in Engineering
Women's Engineering Society

Stephen Thompson

James Rennie Medal
Institution of Civil Engineers

Kim Cooper

Vicky Evans

The Planner's Woman of Influence
Royal Town Planning Institute



COAL DROPS YARD
London, UK

Project awards

Impact at Arup is measured by the positive difference we make, with external recognition serving as an important benchmark. This selection of awards is a good measure of our teams' recent achievements:

AUSTRALIA

505 George Street

Sydney, New South Wales

- MIPIM Architectural Review Future Projects Awards
- Tall Buildings category (Winner)

Anna Meares Velodrome

Brisbane, Queensland

- International Federation of Consulting Engineers FIDIC Awards
- FIDIC (Award of Merit)

Green Square Library

Sydney, New South Wales

- Architectural Review Library Award

Monash Freeway Upgrade, Technical Advisor Role

Melbourne, Victoria

- Consult Australia Awards for Excellence
- Client Service Excellence (Highly Commended)

GERMANY

Blockchain Consulting for Karuna e.V.

Berlin

- Google Impact Challenge Germany (Joint Winner)

CHINA

Energy Mansion

Shenzhen

- Council on Tall Buildings and Urban Habitat
- Best Tall Building (200–299m)

Morpheus

Macau

- Council on Tall Buildings and Urban Habitat
- Fire & Risk Engineering Award

New World Clear Water Bay Sustainability

Hong Kong (Mount Pavilia)

- FuturArc Green Leadership Award
- Residential – Multiple Houses (Award of Merit)
- Quality Building Award
- Residential (Multiple Building) Category (Award of Merit)
- BCI Asia
- Interior Design Awards – Residential (Winner)

South Island Line, Admiralty Station

Hong Kong

- Institution of Civil Engineers
- Brunel Medal for civil engineering excellence (Winner)

Tai Kwun

Hong Kong

- Hong Kong Institution of Engineers
- Grand Award

IRELAND

Tenement Museum, 14 Henrietta Street

Dublin

- Royal Institute of the Architects of Ireland
- RIAI Architecture Awards – Best Conservation and Restoration Project (Winner)
- RIAI Architecture Awards – The Special Jury Award (Winner)

ITALY

Porta Nuova Isola, Bosco Verticale

Milan

- Royal Institute of British Architects
- RIBA Award for International Excellence

KOREA

Amorepacific

Seoul

- Council of Tall Buildings and Urban Habitat
- Best Tall Building (100–199m)

NETHERLANDS

Museum Voorlinden, Caldic Collection – Building Services

Wassenaar

- Royal Institute of British Architects
- RIBA Award for International Excellence

NEW ZEALAND

Kaikoura Rockfall Risk Assessment

Kaikoura, Canterbury

- Institution of Civil Engineers People's Choice Award

PHILIPPINES

Mactan-Cebu International Airport

Lapu-Lapu City

- Centre for Asia Pacific Aviation
- Aviation Awards for Excellence – Medium Airport of the Year (Winner)

SINGAPORE

Tanjong Pagar Centre

Singapore

- Singapore Building Construction Authority Awards
- Design & Engineering Safety Excellence Award – Commercial Category (Excellence award)
- Singapore Association of Consulting Engineers ACES
- ACES Design Excellence Awards – Civil and Structural category (Winner)

SPAIN

Barcelona-El Prat Airport Area Development

Barcelona

- European Council of Spatial Planners
- European Urban and Regional Planning Awards – Airports, Cities and Urban Development (Joint Winner)

USA

181 Fremont Tower

San Francisco, California

- Council on Tall Buildings and Urban Habitat
- Geotechnical Engineering Award
- Structural Engineering Award
- Award of Excellence – Best Tall Building (200–299m)
- Deep Foundations Institute
- Outstanding Project Award (Winner)

Atlantic Yards T2 Modular

451 Dean Street, Brooklyn, New York

- Council on Tall Buildings and Urban Habitat
- Best Tall Building Award
- Construction Award – Award of Excellence

Spruce Goose

Los Angeles, California

- World Architecture News Adaptive Reuse (Winner)

UK

Management Consultancies Association MCA Awards

- Consulting Excellence Firm of the year (Winner)

Claridge's Hotel Basement

London, England

- British Geotechnical Association – Fleming Award (Winner)
- Ground Engineering – Editor's Award

Connswater Community Greenway / East Belfast Flood Alleviation Scheme

County Antrim, Northern Ireland

- British Construction Industry Awards
- Community Engagement Initiative of the Year (Winner)

Design and Dissemination of a New Hand-washing Unit for Emergency Response

- International Society for Neglected Tropical Diseases
- Innovation in the field of WASH (Water, Sanitation and Hygiene) – Programme category (Winner)

New Marlborough Primary School

London, England

- Civic Trust Award (Winner)
- British Construction Industry Awards
- Social Infrastructure Project of the Year (Winner)

Royal Academy of Music

London, England

- British Construction Industry Awards
- Cultural & Leisure Project of the Year (Winner)

Royal Academy of Music – The Susie Sainsbury Theatre and Angela Burgess Recital Hall

London, England

- Royal Institute of British Architects
- RIBA National Award (Winner)
- Architects Journal Retrofit Awards
- Cultural Buildings – Performance and Events (Winner)
- AJ Architecture Awards
- Higher Education Project of the Year (Winner)

V&A Dundee Design Museum

Dundee, Scotland

- Scottish Civil Engineering Awards
- Greatest Contribution to Scotland
- Wallpaper Design Awards
- Best Facade (Winner)

Sir Ove Arup (centre) is pictured here with colleagues Michael Lewis (left) and Sir Jack Zunz (right) on the site of the Sydney Opera House in 1966.



An ethos we've built on

Fifty years ago our firm's founder Sir Ove Arup was approaching retirement. Eager to see the firm flourish when he was no longer at the helm, he started to gather his thoughts into a single ethos. Initially presented to a conference of senior partners in July 1959, by the following year his thinking was delivered to the firm's leaders as the 'Key Speech'.

Sir Ove's thoughts are still the bedrock of our firm, and the starting point for every strategy we set and every decision we make.

OVE'S ETHOS WAS BASED AROUND SIX AIMS:

Quality of work

Total architecture

Humane organisation

Social usefulness

Straight and honourable dealings

Reasonable prosperity of members

Here we look at the current impacts of these aims, drawing on personal stories from members across the firm. These stories demonstrate the relevance of Sir Ove's thinking and the strength of a shared ethos which still binds us together.

THE THINKING THAT SHAPES US TODAY

Sir Ove studied philosophy before he studied engineering. The breadth of his thinking, and his holistic view of the world, shapes the firm we are today and the way we work with others.

From the beginning he believed better results would be achieved if architects, engineers and builders worked together from the start of a project. This untypical, non-linear approach still applies today – although the extent of professional expertise we bring together is far wider than the three professions Sir Ove had in mind.

Whether it's economists or international development experts, ecologists or data scientists, our aim is still to combine our expertise with those we are working with – right at the start of every project. In doing so better solutions emerge, alongside more effective ways of working together. Our multidisciplinary work on a project like Green Square Library in Sydney ([page 88](#)) is a case in point.

THE TROUBLE WITH MONEY

A second strand of Sir Ove's ethos was his views on profit and money. While recognising that the firm needed to be profitable and stable to attract good people and invest in research and development, he never saw the pursuit of profit as an end in itself.

“The trouble with money is that it is a dividing force, not a uniting force, as is the quest for quality or a humanitarian attitude. If we let it divide us, we are sunk as an organisation – at least as a force for good.”

For this reason, he and his fellow Directors gave up their personal shares in the firm and placed ownership in the hands of a Trust, operated on behalf of Arup's members. That's still our model today. It affords us total independence, with no external pressures from shareholders and the freedom to invest in the things we feel matter most – our members, our knowledge, our resources and our communities.

What's also interesting is the financial stability this model has given us. Arup has made a profit in every year it has operated. As Matt Tweedie our Finance Director sets out on [page 48](#), that position continues this year, with another robust performance allowing us to hold true to Sir Ove's beliefs and their positive impacts for our clients and society as a whole.



Daniel Imade
Information Management Group

**SHARING AND STRENGTHENING
KNOWLEDGE**

Building the thriving, creative culture Sir Ove Arup envisaged for our firm doesn't happen by chance. It's something that needs to be nurtured. One of the ways we do that is through the Arup Library.

Founded 60 years ago, the library is an integral part of what our Information Management Group leader, Julian Diamond, calls our 'culture of enquiry'.

"Having access to information and knowing that we don't always know the right answer ourselves was a foundation stone for the culture that enabled the library function to be created, to exist and to flourish," said Julian.

The notion of a library as a place to not just find information from outside the firm, but also to connect with individuals within it, captures what the library is all about today. Managed by full-time library professionals like Daniel Imade, it echoes the essence of Sir Ove's collaborative ethos. It's also an important source for precise, technical information not always available online.

BEYOND WORDS

The picture we all have of a library is a hushed space with row upon row of books. But right from the outset Arup has recognised the power and importance of imagery too.

Daniel Imade joined Arup in 1994, after working for the UK Civil Service on the early development of digital statutory information. His educational background in Urban Rehabilitation and Conservation drew him to a firm looking to digitise its own vast collection of project images.

As Daniel explains: “When I joined we had a collection of over 250,000 images stored as prints and slides. Engineers would arrive in the library to create presentations using a light table and a slide carousel. Digitising these images was clearly the future, but the task we faced was huge.”

With computing power a fraction of what it is today, batches of 100 slides were sent off for scanning, with a digitised library (Asset Bank) gradually emerging to meet the needs of an increasingly digital firm.

Today the image collection is almost twice the size it was in the 90s, with smartphone technology turning every member into a potential photographer. This makes quality control difficult, but Daniel’s view is that encouraging everyone to ‘shoot and share’ is overwhelmingly positive, provided the right controls are in place for asset management.

New technology continues to create further opportunities. According to Daniel: “Artificial intelligence is an interesting prospect in terms of automatically tagging and archiving images.” Meanwhile there’s a continual pursuit to make Arup’s vast Asset Bank accessible to members wherever they are working. As Daniel points out: “Images aren’t solely the preserve of marketing and business development teams. They are a visual record of the amazing solutions we create – vital to the process of extending our knowledge and pushing new boundaries.”

Beyond Daniel’s quest to further extend the reach of our Asset Bank, other teams are also expanding the scope of our information management services.

ARUP LIBRARY 1980s, London, UK



“Images are a visual record of the amazing things we create – vital to the process of extending our knowledge and pushing new boundaries.”

DANIEL IMADE
Information Management Group

Around the world, the library team is pioneering new tools like chat bots, apps and mobile access to complement its library services. Meanwhile, as data on projects becomes more and more important, we are looking at improved ways to store, manage and share this data to further enhance the solutions we develop.

Sir Ove Arup said: “I can’t see the point in having such a large firm with offices all over the world unless there is something which binds us together.” Daniel and his colleagues in the Information Management Group are a huge part of this collaborative mindset. Whether it’s technical information, images or data – the assets and insights we share across the firm are essential to the quality of the work we produce.

Excellence through innovation

At Arup we have long had a collective mindset that's not satisfied with 'good enough' or 'second-rate'. This mindset is about excellence and its symbiotic relationship with innovation.

At a time when technology is rapidly transforming every aspect of our lives, this is more the case than ever before. No firm in our field can claim to offer excellence if it's not constantly fuelling innovation through foresight, research, and professional and technological development. Across the firm we've been doing that again this year.

THE DIGITAL DIMENSION

Our drive to exploit the ever-expanding potential of digital technology covered four areas this year:

Data

Automation

Digital services

Digital products

With data, one of the primary tasks has been the development of new firm-wide data architecture. This will allow our teams to 'innovate at the edge and scale in the centre' as data increasingly informs all our processes and all our work.

Automation and rapid development of technologies like machine learning and artificial intelligence have progressed on two fronts this year. Automation is allowing more routine production tasks to be undertaken at greater speed and higher consistency. Meanwhile, machine learning and artificial intelligence enable us to explore wider parameters on projects than ever before. Our work applying machine-learning techniques to natural flood management ([page 26](#)) is one of a number of examples.

With digital services we are integrating our core expertise in consulting, engineering, planning and design, with newer skills in data, modelling, products and advanced digital technologies. This year we have set up four 'accelerator programmes' covering intelligent buildings, aviation, infrastructure and smart places. An example of this approach is the development of our 'Real Time Airport' technology which allows every facet of an airport's operations to be monitored and any issues to be anticipated and acted upon.

With digital products our aim is to build software at scale, utilising our expertise and domain knowledge, to solve common problems in the built environment.

THE VALUE OF FORESIGHT

Our Foresight team investigates issues that require a holistic look at the future.

A primary output is the 'Drivers for Change' series, examining 25 important issues impacting our societies and markets across 10 topics – from urbanisation to poverty. This year saw the publication of a new set entitled 'Climate Change and Ocean Health'. This was curated by Australian environmental scientist and explorer Tim Jarvis, for the One Ocean Exploration Zone.

PRACTICAL INNOVATION

Innovation means different things to different clients. For some, there's a desire to expand the art of the possible, asking us to create solutions that are breathtaking in their scope and vision. V&A Dundee in Scotland ([page 94](#)) is the epitome of this thinking – with a structurally daring design beautifully realised through new techniques and technologies.

For other clients, innovation is all about efficiency – finding ways for the largest and most demanding projects to be completed at greater speed and lower cost. Our advisory services work on the London Power Tunnels ([page 104](#)) demonstrates this approach.

Finally, innovation also has a human dimension, with teams or individuals combining ideas to make a tangible difference to people's daily lives. Our work on the Women's Safer City project in the Solomon Islands ([page 120](#)) does just this. It brings together different social development techniques and urban planning strategies to improve the lives of vulnerable people.

**MACHINE LEARNING AIDS THE
FIGHT AGAINST FLOODING**

Around the world climate change is having a huge impact on the stability of our water sources. In some regions, drought is a major issue with places as far apart as California and Melbourne having their driest years on record.

In other areas the opposite is true, with storms and periods of intense rainfall causing recent flash floods and unpredictable water surges in locations like France, Iran, East Africa and Bangladesh.

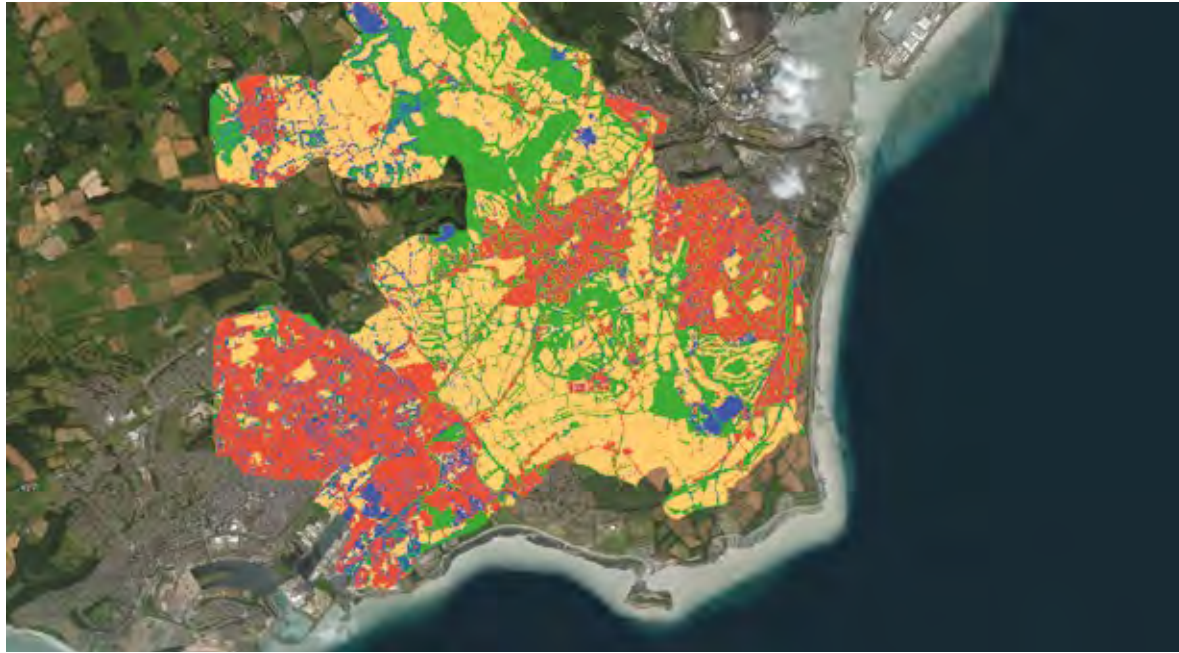
Traditional engineering solutions like dams and storm drains have long been a response to these issues. That still remains the case, but as major structural interventions they take significant time and money to implement. With flooding a growing threat around the world, new solutions are urgently needed. That's a challenge that Arup members like Karoline Lende are eager to address.

“Climate change is a fact of life. It’s causing more and more flash floods with big consequences for local communities.”

KAROLINELENDE
Advanced Digital Engineering

Karoline Lende
Advanced Digital Engineering





DIGITALLY NATIVE

As part of our Advanced Digital Engineering team, Karoline is interested in applying cutting-edge technology to difficult problems. A civil engineering graduate from Imperial College, London, she joined Arup three years ago. Over her time with the firm she’s developed a broad digital engineering skillset, ranging from using Computational Fluid Dynamics (CFD) to predict the flow of water and air, to using finite element modelling to design and analyse offshore structures.

With the aim of exploring the use of emerging digital technologies, Karoline and her colleagues submitted an application for Arup’s Global Research Challenge, which invites everyone in the firm to look at new solutions for major global issues.

The Advanced Digital Engineering team put forward a proposal looking at how machine learning could be used in natural flood management techniques. These techniques are based on low-cost, small-scale interventions – like planting trees – to manage flood risk by slowing, storing and filtering surface water run-off.

The fundamental question was, where and how best can these techniques be applied? Karoline and her colleagues felt they had an interesting answer.

MAPPING IMPACTS

Working with Digital Globe, specialists in high resolution satellite imagery, the Arup team proposed looking at land use in two catchment areas in the UK – Barry and Sheffield – literally one pixel at a time. This entailed building and training in-house machine learning algorithms to provide a map at 40,000 times higher resolution than the typical open source data sets. This allowed the accurate mapping of existing land use and the capability to predict where natural flood management techniques could have the biggest impact.

Results to date are impressive, with the machine learning models providing the high-resolution, up-to-date mapping data needed for optimisation schemes to automatically identify where natural flood management techniques will be most effective.

The system is about to be trialled by the UK Environment Agency. They are interested in the ability to map potential locations for interventions quickly and at scale. Ultimately the aim is that this exciting technology can be applied globally, helping mitigate flooding in regions where it increasingly has a devastating impact.

PERSONAL PERSPECTIVE

For Karoline, the machine learning project has offered a great opportunity to develop her skills in new ways. She said: “Before this I hadn’t worked on a project with machine learning. You can undertake training courses but there’s no substitute for learning and exploring on the job. I’m now working with the team to apply these skills to other projects. We are currently looking at ways to use the technology to automatically extract information from engineering drawings and to map fatigue damage on offshore wind turbines.”

What’s also interesting for Karoline is the potential for technology to combat big global issues: “Climate change is a fact of life. It’s causing more and more flash floods with big consequences for local communities. Our machine learning techniques enable sustainable solutions to be created more quickly. Rather than relying only on big structural interventions like dams, we can help communities protect themselves through natural means. This has added benefits for ecosystems and local water quality too. I hope we can spread the impact globally in the years to come.”



Supporting & inspiring our people

Growth at Arup is never an end in itself. Our aim is to meet the needs of our clients to the best of our abilities and to carefully add skills with lasting value. As we do this, it's vital we continue to adhere to the aim of being a 'humane organisation', one where everyone feels supported and inspired. Proactively making this a meaningful reality for every member is a continuous process.

OUR APPROACH

We now have more than 15,800 members worldwide. We are growing into new business areas – often connected to sustainable development and the new digitally led economy. And the expectations of our members and our clients around how we do things are changing.

With this in mind, we are at the start of a journey that will see us actively evolving, sharing and reinforcing our culture and values. We are also developing better systems and processes to ensure consistency and fairness, good decision-making, and compliance with myriad local laws and regulations. Finally, we are ensuring that our professional development activities – focused around Arup University – continue to be sector leading. This involves building skills in areas like artificial intelligence, and constantly expanding the types of learning opportunities we offer everyone.

RECRUITING AND IMPROVING

The skillsets we need are changing. We still recruit the best engineers, architects and planners; to that mix we are now adding people with skills in areas like data science, circular economics and workplace wellbeing.

For graduates, Arup continues to enjoy a strong reputation. We attracted applications from over 35,000 students last year, recruiting 726 to permanent roles. In growing areas like digital and advisory services we are creating new links with a broader range of university subjects and building stronger networks with bodies in other professional disciplines.

We are also improving all aspects of diversity, to strengthen an inclusive work environment that's based on merit, fairness and respect. In a traditionally male-dominated sector, we want to improve our gender balance by reaching a target of at least 40% female members as soon as we responsibly can. We have made further progress on that this year with an increase from 34.2% to 35.9% across the firm. We need to go further and will maintain our efforts until our target is exceeded. This year, we have also become a signatory to the UN's Valuable 500 Compact, strengthening our commitment to meeting the needs of members with disabilities.

LEARNING AND LEADING

Our programmes and learning tools cover all career stages, from professional training to leadership skills.

One example is our Master Modules, which are designed to advance our skills in topics of strategic importance to the firm. Students attending these modules are challenged by academic, masters-level work. They also develop cross-disciplinary understanding and networks across the firm. Current modules include Machine Learning and Artificial Intelligence in the Built Environment, Resilience of Urban Systems, and Autonomous Transport and New Mobility.

NEW IDEAS

As a firm committed to innovation, it's important that we embrace new ideas and techniques for our people too.

In Sydney we have set up mindfulness workshops attended by over 1,000 members in the past few years. The positive feedback we've received is encouraging us to expand the concept across all our regions. We have also launched a global Wellbeing Framework this year. Anchored in the principles of the UN Sustainable Development Goals it sets out the practical steps we need to take to ensure all our members are comfortable, healthy and happy.

Ultimately, we are applying the same high level of ambition to our members as we do to our clients and projects. We want to be an organisation where everyone flourishes – collectively and individually.



Biao Lu
Urban Planning

**CHANGING THE WAY WE
THINK ABOUT DESIGN**

Across Arup we are eager to see people think in new ways and challenge conventions. One way we nurture this is through our global Design School programme.

Funded by Arup University, the programme brings together a select group of nominees from a variety of disciplines – engineers to marketers, ecologists to technologists – strengthening skills in design in its broadest possible definition. Around 500 of our members take part every year.

Each of our five regions holds at least one Design School annually. Based loosely on the university ‘studio’ method of design teaching, external presenters and our own leaders set inspiring, practical challenges that help people think and work in new and inventive ways. Over the years we have invited a wide range of people to present at these events, including world speed record holders, fashion designers, world-famous chefs and polar explorers. Recent Design School themes have included ‘More for Less’, ‘Journeys of the Future’, ‘Expecting the Unexpected’ and ‘Un-Design’.

This year’s ‘Planet B’ theme in East Asia continued that tradition, providing a highly relevant and topical subject for Urban Planner Biao Lu to explore with 34 members in Hong Kong.

THE WASTE OPPORTUNITY

Waste is a by-product of urbanisation and economic development. As nations and cities become more populated and prosperous, people use more products and services, and the volume of waste expands proportionally.

With the publication of our 'Urban Bio Loop' report, Arup looked at ways to change this paradigm. Specifically, we looked at whether waste that's normally sent to landfill, incineration or composting could be diverted into resources for new materials, before being fed back into the biological cycle at the end of its service life.

Exploring this thinking was what the 'Planet B' theme was all about. Biao and the other participants began with a revealing exercise:

"Ahead of the programme we were asked to create a three-day 'trash log' and film a short video," said Biao. "Results were alarming, confirming exactly how much waste we all generate on a daily basis."

With a clear picture of their personal waste footprints, Biao and the rest of the Design School participants started to look at ways to develop a less wasteful future.

NOTHING LEFTOVER

A cooking workshop was one unexpected activity. As Biao explains: "Under the guidance of Foodlink, a local charity dedicated to tackling the problem of food waste, and two chefs from the French International School, each team tried to make effective use of food leftovers. Creating a three-course meal was a challenging task, but with a little creativity, we now all see leftovers in a different way."

"I found the results alarming, confirming exactly how much waste we all generate on a daily basis."

BIAO LU

Urban Planning



DESIGN SCHOOL 2019

Hong Kong, China



Biao and his colleagues were then asked to tackle some real-life problems facing the food and beverage industry. One of these involved designing and physically building food delivery containers by reusing waste material. According to Biao the results were interesting but needed to be tested in-use: "To put our designs to the test, the six teams competed against each other on a delivery challenge consisting of running, cycling and walking. The winner was the team that delivered all the food and drinks in the fastest time and with the least spillage."

For Biao, the Design School was a great opportunity to think creatively about waste.

More broadly it brought colleagues together from offices in Australia, Canada, mainland China, Hong Kong, Japan, Macau, Poland, Taiwan and the UK. Sharing diverse perspectives and creating stronger, multidisciplinary networks is a big part of why our Design School programme, now in its 20th year, continues to be so valuable.

Most governments, non-governmental organisations, businesses and scientists agree – the world is approaching a developmental tipping point and radical change is urgently needed.

Increasing urbanisation and the emerging middle classes have generated wealth and prosperity for many. Yet inequity, growth in consumption and unsustainable production methods mean resources are running out.

The effects of climate change are increasingly tangible, and no one is exempt from the extreme risks posed by a warming world. There's also a growing need for resilience – to improve the ability of cities and communities to adapt to rapidly changing circumstances and increasing risk.

Against this background our firm made a clear commitment to use the United Nations Sustainable Development Goals (SDGs) as a framework to take positive action. With our expertise, diversity of thinking and independent culture we firmly believe we can use the SDGs to support the quest for a safe, sustainable and resilient future – for all.

MAKING THE GREATEST IMPACT

The SDGs comprise 17 goals and 169 targets. All of them are critically important, with myriad links across the different goals.

As a firm our focus is on the built environment. This means that while we will constantly reference all the goals, there are four areas where we acknowledge we can have the greatest impact:

Clean water and sanitation

Affordable and clean energy

Industry, innovation and infrastructure

Sustainable cities and communities

Helpfully, these four areas align with our firm's strategy. This year we have been looking at each of these areas in detail to understand what the impacts of aligning to the SDGs will be. We have also been applying this thinking to current projects, ensuring that positive outcomes remain at the forefront of our approach.

CLEAN WATER AND SANITATION

The challenges climate change has created for water contrast starkly between record periods of drought for some regions, and increasing flooding in others. Access to clean drinking water and sanitation remain critical challenges for millions of people in the developing world.

Our City Water Resilience Approach ([page 110](#)) demonstrates how systematic thinking can create positive outcomes in cities as diverse as Manchester and Mexico City. Meanwhile, initiatives like our WaterUp digital tool ([page 122](#)) show what can be achieved by empowering local communities to manage their own water resources more effectively.

AFFORDABLE AND CLEAN ENERGY

Supporting energy transitions that will enable a net-zero carbon future is a priority for our firm.

Tidal energy is one interesting possibility, and our work on the Tidal Kite ([page 108](#)) is an example of how evolving technology is turning interesting concepts into practical, scalable opportunities. Hydrogen, likewise, has long been mooted as a low-carbon alternative to oil and gas. Our work on a new Hydrogen Production and Refuelling Facility in New Zealand ([page 106](#)) is a significant test case with international implications.

INDUSTRY, INNOVATION AND INFRASTRUCTURE

Much of our work in infrastructure focuses on the need to connect people. Major projects like Cityringen in Copenhagen ([page 74](#)) demonstrate the benefits that modern, digitally enabled rail can bring.

One interesting trend is the repurposing of former industrial spaces. Coal Drops Yard in London – which has seen a historic railway area transformed into a vibrant city quarter ([page 54](#)) – and Smakkelaarspark in the Netherlands, which is setting new standards for sustainable urban development ([page 62](#)), are but two examples.

SUSTAINABLE CITIES AND COMMUNITIES

We are working across the planning, transport, utilities and property sectors to make urban environments more sustainable for businesses and residents alike.

Scale is an interesting factor here. Small Islands Developing States (SIDS) are particularly affected by climate change. Our SIDS strategy work ([page 112](#)) is helping them plan for and mitigate the worst of these issues.

Meanwhile in major cities like New York and Hong Kong, the work on buildings like Solar Carve ([page 64](#)) and M+ Museum ([page 92](#)) are driven by an ambitiously sustainable agenda.

When, in 2018, we made a firm commitment to fully align our activities with the United Nations Sustainable Development Goals (SDGs), that pledge wasn't made lightly. We were fully aware that it would impact all our actions and all our work.

However, the scope of the SDGs is substantial. It's not always easy to fully understand what they will mean in practice. For that reason, when a project emerged that embodies every facet, Nicolo Guariento, Elliott More and our team in Denmark were eager to grasp the opportunity.

“The 17 UN SDGs have been raised from checklist to active design parameters to set a new standard for building in an urban context.”

UN17 COMPETITION JURY



Nicolo Guariento
Building Physics
Elliott More
Sustainable Development

AN AMBITIOUS AGENDA

The brief for the UN17 Village in Ørestad, Copenhagen, was ambitious: create a large, residential development of 400 units that aligns with all 17 of the SDGs.

These goals cover social factors like poverty, health, education, equality, social cohesion and economic growth. They also impact physical elements directly relating to sustainability and climate change like water use, biodiversity, building materials, energy supply and infrastructure.

In collaboration with Lendager Architects, Arup's team won the competition to design the groundbreaking development.

Elliott More, who leads on the SDGs in our Copenhagen office, picks up the story: "Our approach was based on using the SDGs as a comprehensive design framework."

This involved the team translating each of the 169 targets into context-specific challenges, and finding meaningful solutions that could be implemented within the site boundary.

In doing this the Arup team explored concepts that wouldn't normally be considered in a building's design. They realised the importance of designing in spaces for shared community activities, prioritising health and wellbeing, and creating restorative or regenerative solutions to improve local ecological systems.

Overall, while using the SDGs added complexity to the design, it ultimately led to a better development that considers the wellbeing of its residents, the local community and the natural environment.



UN17 VILLAGE

Copenhagen, Denmark



Nicolo Guariento led Arup's involvement. "At the beginning of the project we engaged the design team and the client in a discovery process to develop a vision based on 17 challenges – one challenge for each SDG."

The scheme will support biodiversity by introducing local flora and fauna onto the green roofs and the common spaces, and promote the growth of local food. The building complex will be constructed entirely from recycled materials available within Denmark or natural materials like timber from Scandinavia. In addition, the village will use 100% renewable energy sources and will be able to collect 1.5 million litres of rainwater every year for recycling and recreational use.

For the community of UN17 Village, the benefits of this groundbreaking development go well beyond energy bills and environmental factors. The UN SDGs are deliberately holistic and interlinked. Social factors are vitally important. For this reason, the scheme aims to reinterpret the tight-knit community feel of a village.

There's a wide range of housing types to suit people with different needs and different incomes. There is also a focus on security, and the provision of community facilities and open spaces so that there are lots of places across the neighbourhood where people can meet and interact.

The Arup team's ambitious approach to super-sustainable development goes beyond the UN17 Village alone. Nicolo and Elliott want to share their new knowledge to improve other projects too: "We are learning so much with this project. We want to take that insight and share it with others – expanding knowledge across the built environment and improving lives for other communities," says Elliott.

This approach, and the enthusiasm it's created across our firm, is exactly what aligning with the UN SDGs is all about. We all recognise that the issues they address are critical and urgent. Working in this way has to be the way forward.

Making ourselves useful

Rooted in our long-held commitments to humanitarianism and social usefulness, our community engagement programme is an expression of who we are, more than what we do.

Across the firm there's a collective will to make a positive impact in communities that need it most. We also recognise that our ability to solve complex technical problems provides us with both an opportunity and a responsibility to make a meaningful difference.

FOUR-STREAM APPROACH

Community engagement work at Arup is approached through four streams:

The Arup Global Challenge

Disaster response and recovery

Developing countries

Local engagement

Carefully balanced and interlinked, these streams are the means through which we improve the lives of vulnerable, marginalised and disadvantaged people in communities across the world.

ARUP GLOBAL CHALLENGE

Launched in 2017, the Arup Global Challenge is a £5m five-year initiative that aims to solve systemic issues with innovative solutions – typically via larger projects.

Teams across the firm are asked to submit thought-provoking proposals. This year nine were chosen for funding and further development.

One example is the WaterUp initiative ([page 122](#)). This has seen our team gathering information about traditional water management techniques in India and Colombia. This information will be shared globally through the WaterUp app, enabling communities across the world to improve their own water resilience.

Another is the Smart Water project with Fields of Life, our charity partner in Uganda. Arup is developing a system to improve the reliability of hand pumps through effective monitoring. The system, which is underpinned by human-based design, harnesses 'internet of things' technology to enable communities to make informed management decisions and implement preventative maintenance.

DISASTER RESPONSE AND RECOVERY

This stream enables our people to respond to humanitarian disasters by partnering with aid agencies and other partners on the ground. We also provide remote technical expertise and targeted financial support.

A prime example this year has been our continuing work with Rohingya refugees on the borders with Bangladesh. More than 750,000 people have fled Myanmar since 2017. One of the primary challenges they face is the impact of cyclones on their basic bamboo shelters. A sustained programme of in-camp technical support is helping to improve this situation.

DEVELOPING COUNTRIES

Our work in developing countries involves working with a wide range of community-based organisations. Our aim is to use our technical skills to enhance their local knowledge and impact.

A great example of this kind of partnership is our ongoing work with Pollinate Energy in India and Nepal. Pollinate Energy is a social enterprise that brings life-changing products, like solar lights, water filters and clean cooking facilities, to people living in India's urban slums and across rural Nepal. Our skills in international development, energy and environmental management are combining to help Pollinate meet its goal of helping over a million people by 2020.

LOCAL ENGAGEMENT

This final stream sees our members providing their time and expertise to organisations and communities based close to their offices. This area is the largest part of our community engagement programme.

A good example of the work we do is the Hackney Winter Night Shelters project. These shelters provide homeless people with emergency sleeping accommodation in the East End of London. Our fire risk assessments ensure the 15 venues are safe for vulnerable people sheltering from the worst of London's winter weather.

“We're excited and grateful to continue our wonderful partnership with Arup. Together we're delivering real impact for the communities we serve and accelerating Pollinate's ambitious goal to reach more than one million people by 2020.”

ALEXIE SELLER
CEO, Pollinate Group



Stephanie Gulliver
Electrical Engineering

**CREATING OPPORTUNITY
IN ETHIOPIA**

Energy is an important issue across the developing world. It's critical to economic growth, but with many parts of the world 'off-grid', the infrastructure investment required for change was simply too high. At least until now...

Micro-grid systems, including those powered by solar photovoltaic panels, are starting to have a transformative impact. Completely stand-alone and increasingly affordable, they have the capacity to bring power to the remotest regions.

One such place is the Dolla Ado region of Ethiopia. Here, a team from Arup that includes Senior Electrical Engineer Stephanie Gulliver worked in close partnership with Engineers Without Borders (EWB). Their aim was to provide technical support to the United Nations High Commission for Refugees (UNHCR) in its quest to improve the lives of Somalian refugees.

LIGHTING UP LIVES

There are approximately 220,000 refugees living at camps in the Dollo Ado region. They have fled Somalia to escape famine, drought, civil war and violence.

Stephanie, and a team from our San Francisco office, worked with EWB to bring new forms of renewable energy to the camps. As she explains: “By installing 52 micro-grids, the project will bring clean, reliable and affordable electricity to the camps and create jobs for refugees.”

The micro-grid systems use stand-alone/off-grid technology built around solar photovoltaic panels and battery storage. Our team, with support from Arup’s Community Engagement Fund, has assisted with feasibility studies, design work and construction supervision. They have also trained refugees in the fundamentals of electricity generation, including safety and installation methods.

For Stephanie, the project took on a more personal dimension when she spent time working with teams on the ground:

“I was passionate about the project and really wanted to work with the community in Ethiopia to get the micro-grids properly established. I completed a three-month volunteer assignment embedded with UNHCR. As well as overseeing construction, I helped train 60 refugees as solar technicians, providing them with a trade and giving the community expertise they can call on.”



▲
MICRO-GRID TRAINING
Dollo Ado region, Ethiopia

“I’m 22 years old and this is my first job. I’m very grateful that UNHCR is training us and giving us the chance to work. For females, these opportunities don’t come around very often, but I’d love to become a woman in engineering someday.”

SOLAR TECHNICIAN
Hilaweyn Camp

In Stephanie’s view the impact of the work in Dollo Ado has been transformative:

“It’s amazing to see the impact the micro-grids are having. Power is fundamental not just to the basics of life, like lighting and cooking, but to critical social factors like health, education and employment.”

UNHCR’s goal is for the energy cooperatives to become self-reliant – making a profit by operating the micro-grids and providing technical maintenance services within the refugee camps.

They are continuing to support this goal by providing regular remote support – ensuring that successes to date become the foundation for long-term sustainable change.

Financial summary

THE STRENGTH TO STAY TRUE TO OUR AIMS

As we have outlined throughout this report, Sir Ove Arup built this firm on strong foundations. Two pillars of this were his belief in ‘straight and honourable dealings’, and in ‘reasonable prosperity for members’. Neither happens by itself.

We make stringent efforts to ensure that our governance and corporate ethics are beyond reproach. We likewise manage our finances to ensure that we have the stability and strength to attract and retain people of real quality, and invest in the research and new thinking that inspires them to achieve great things. This year has seen us maintain those beliefs, strengthening the platform we need to do even more work of quality in the years ahead.

PERFORMANCE

This year has seen another robust financial performance for Arup in an environment that remains unpredictable and sometimes turbulent. Revenue has grown by 9.9% to £1.71bn, with an operating profit (before staff profit-sharing) of £135.4m. This performance continues the trend over the past four years of maintaining profits around 10%. Doing so allows us to plan and sustain investment in critical areas like research, technology and member development.

Profit-sharing with staff, as a percentage of total employment costs, was 10.3%, again similar to recent years. We have also ended the financial year with a healthy forward order book of £1.36bn, a good measure of the trust clients place in a firm they believe offers the right mix of innovative thinking and quality results.

Of note has been our performance in North America. Revenue across the USA and Canada has grown by 6.4% as we have become an increasing presence in both markets – particularly in transport infrastructure. Our work on Montreal’s Champlain Bridge is but one example of many in this space.

South East Asia, another area of strategic focus for the firm, is also performing well. Large projects like Changi Airport show our strength in the region, as does the significant development of our offices in Indonesia and Malaysia.

The UK remains a cornerstone of Arup. Performance here remains strong, with increased diversification, particularly in advisory and digital services. Brexit remains a challenge on the horizon, but we are confident that our robust financial position and diversified global services place us in a good position to respond effectively.

2018/19 has been a year of notable investment in strategic priorities. Commitments to the digital transformation of our business and to fully aligning with the UN Sustainable Development Goals require sustained funding for new technology, new services, new forms of professional development and new members with different skillsets. We have made those investments this year and will continue to do so in the future as we meet and surpass the commitments we have made.

In some cases, we have also been prepared to back our beliefs with hard capital. Innovative designs like ‘Artus’ – an air-conditioning unit we have licensed to Airedale International – have seen us provide funding through Arup Ventures with the aim of turning great ideas into tangible products. We envisage making further selective investments like this in the future.

In conclusion, we reach the turn of the decade with quiet confidence. Sir Ove’s vision for this firm was never driven by the pursuit of profit above all else. Instead we wanted to see a strong, stable firm that is able to attract great people and give them the platform to do outstanding work. I am pleased that many years later we are staying true to these worthy aims.



MATTHEW TWEEDIE
Group Finance Director

REVENUE (£M)

2015	1,125
2016	1,240
2017	1,510
2018	1,560
2019	1,714

OPERATING PROFIT (£M)

Before staff profit-sharing

2015	89
2016	126
2017	175
2018	190
2019	135

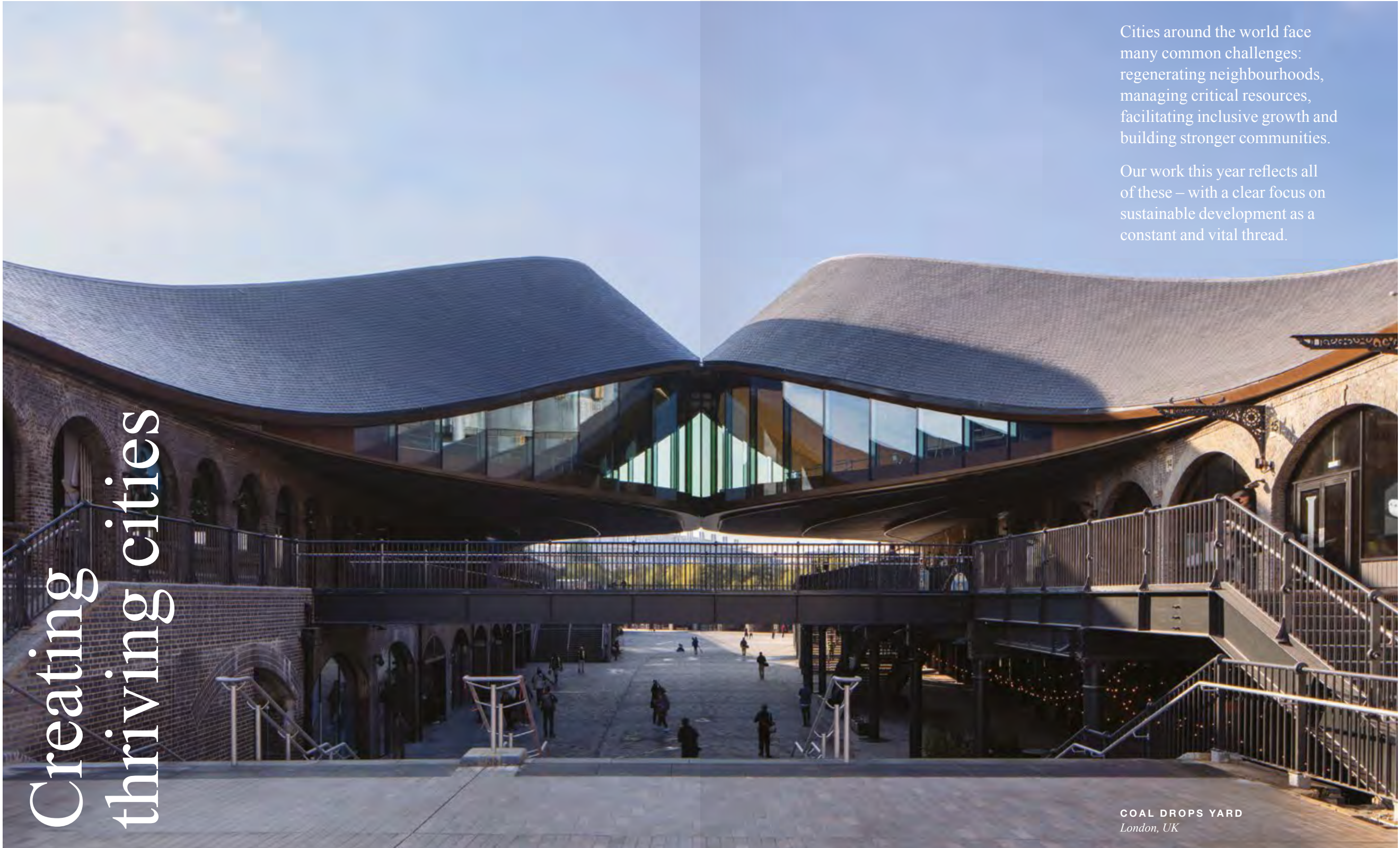
Creating
thriving cities — 52

Connecting
people & places — 70

Shaping inspirational
spaces — 84

Sustaining the
resources we need — 102

Supporting diverse
communities — 116



Creating thriving cities

Cities around the world face many common challenges: regenerating neighbourhoods, managing critical resources, facilitating inclusive growth and building stronger communities.

Our work this year reflects all of these – with a clear focus on sustainable development as a constant and vital thread.

COAL DROPS YARD
London, UK



Coal Drops Yard *London, UK*

FROM DISREPAIR TO DESTINATION

Located at the heart of London's King's Cross, Coal Drops Yard has an interesting history.

As its name suggests, it was originally built in the 1850s to store and distribute coal, and was subsequently used to house everything from warehouses and workshops, to film sets and nightclubs.

In more recent times these buildings fell into disrepair. With the King's Cross area as a whole undergoing radical transformation, the opportunity to redevelop Coal Drops Yard into a landmark retail destination became clear.

Arup's work on this project has been significant, encompassing heritage, materials and geotechnical consultancy, structural and façade engineering.

Our team worked closely with architects Heatherwick Studio on the regeneration of the historic buildings, with the centrepiece being a stunning sculptured roof that unites the two Coal Drops buildings. This creates a glazed retail unit at the upper level with a public plaza below.



This project is a fitting example of our skills in repurposing historic buildings. We combined our conservation capabilities with expertise in contemporary structural features – ensuring that the new additions remained sympathetic to the site and preserving the original fabric of the heritage buildings.

Today, Coal Drops Yard offers visitors a destination with a rich mix of boutiques, restaurants, bars and cafés – turning a disused industrial space into a vibrant new quarter.

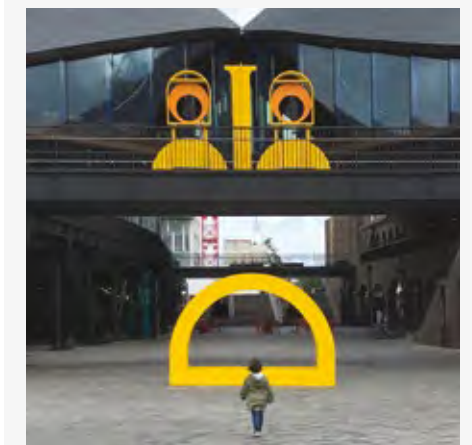
The project also marks the latest chapter in Arup’s 35-year involvement in the comprehensive transformation of the whole King’s Cross area. Following on from the redevelopment of the adjacent St Pancras International and King’s Cross train stations, this has also seen us providing engineering and design services for other historic buildings, including Gasholders London, the Midland Goods Shed and the Stanley Building.

“This has genuinely been a once-in-a-lifetime project for all involved, due to the scale of the ambition and the complexities of the heritage, buildings and retail offer... Arup has been absolutely instrumental in helping us to achieve a world-class design that will not, and cannot, ever be replicated anywhere else and we are extremely grateful.”

MORWENNA HALL
COO Argent



© **BLISSFULLYCHRIS_** · 2019
I ALMOST didn't spill my coffee #coaldropsyard



© **ALESMISHIMA** · 2019
One of #itsnicethat Double Take installations at #coaldropsyard



China Resources Headquarters *Shenzhen, China*

REACHING FOR THE SKY

The growth of Shenzhen in China has been astonishing. From a market town of around 30,000 inhabitants in the 1970s, the population now exceeds 12 million people.

This growth has been fuelled in part by the city's role as a foreign investment hub and financial centre, with the local government consistently expanding the scale and scope of business developments across the city. One such area is Shenzhen Bay, which has recently been developed as a headquarters destination for Chinese and international companies.

The 392.5m tall China Resources Headquarters sits at the heart of Shenzhen Bay. This arresting, 'bamboo shoot' shaped building was a collaboration between our Shenzhen, Hong Kong and New York offices and American architectural practice Kohn Pedersen Fox, across six years of design. Our team provided structural engineering, geotechnics, façade design and fire safety strategy services across the project.



We used a range of innovative design features and advanced structural optimisation technologies to improve the usability of the tower and the cost-effectiveness of its construction. With the tapering slender shape of the overall building, we moved away from the more traditional mega-column and sparse-column frames. Instead, we designed a unique structural system of 56 external columns that spring from diagrids at the bottom of the building and converge at the top into a stunning crystal cap known as the Sky Hall. This is the first time such a system has been used for a mega-tall building in a seismic area in mainland China.

Other aspects of our design approach resulted in benefits for the building owners and occupiers. Eccentric beam-column connections were used for the perimeter frame, which created a column-free interior space, while a tapered core design increased net floor area.

We also addressed issues of occupant safety and comfort for a tall building susceptible to typhoon wind loads. Following detailed wind tunnel testing, the skyscraper's structural design was fine-tuned to improve behaviour under different wind loads. Viscous outrigger dampers were used to minimise vibration and create a more comfortable environment for occupants – again, a first in mainland China.

The result is a state-of-the-art tower that is not only elegant but highly functional – fully meeting the needs of Shenzhen's ever-growing business community.



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The bamboo shoots in spring.
China Resources Headquarter #shenzhen



© NOPEDIAL · 2019
The China Resources HQ (aka Spring Bamboo)
#chinaresourcesheadquarters #springbamboo

Smakkelaarspark Utrecht, Netherlands

FROM UNLOVED TO UNMATCHED

The previously unloved Smakkelaarsveld area, next to Utrecht's central railway station, will soon be redeveloped into a stunning green space and mixed-use development – turning this abandoned tract of land into a destination in its own right.

As with many urban redevelopment projects, the City Council needed to address problems of noise, congestion, and tangled transport and utility intersections. The Council also wanted to see a landmark urban design project that would set unmatched standards for Utrecht in terms of sustainable living.

Working as part of a consortium with Lingotto, Studionedots, ZUS and VKZ, Arup addressed these challenges by combining sustainable ingenuity with the latest design technology.

Specifically, the consortium's winning bid was based on a parametric design methodology, which uses algorithms to optimise the scheme design against multiple sustainability key performance indicators, such as daylight, noise and energy.

One example of this approach is the orientation of apartments at Smakkelaarspark. At its simplest, our use of design technology will enable the maximum number of apartments to receive the best possible views across the city and the park.

However, benefits go further than that.

Increased natural daylight will improve energy efficiency and the orientation enhances air flow through the site while also blocking noise from the adjacent road and rail network. Optimising views towards the park also improves safety for the local community.

When complete, the Smakkelaarspark development will be centred around a new green space, surrounded by residential blocks, offices and parking, and intersected by an extension of the Leidsche Rijn canal. A light rail connection will also run beneath the entire site.

Future occupants will benefit not only from a development rich in green space and community amenities, but from use of sustainable energy too. The area has been designed to be fully energy-neutral. This will allow more than 50% of the buildings' energy to come from photovoltaic panels positioned on the roof and façades – reducing costs and carbon emissions for the whole community.

Flexibility has also been built into the design to maximise the lifespan of the development. With relatively simple interventions, the buildings can be transformed from office to residential use or vice versa – ensuring that Smakkelaarspark remains relevant to the next generation of Utrecht's residents and businesses.

50%+

PV-generated energy

170,000

Passengers pass every day through Utrecht Station located a two-minute walk away





Solar Carve Tower New York, USA

CARVING OUT INSPIRATION

The demands we make of office spaces are changing. Where maximising value from each square metre of space was once the primary driver, other considerations are now becoming equally important to businesses looking to attract and retain the best talent.

People want enjoyable, inspiring and energy-efficient workspaces. The new Solar Carve Tower at 40 Tenth Avenue in Manhattan is a prime example of a building that's responding to these expectations.

Located in New York's Meatpacking District, the building offers outstanding views of the Hudson River, with access to outside space at almost every level. These spaces culminate in a landscaped top-floor roof garden, offering the building's users a tranquil escape from a busy working environment.

In thinking about the experience for building users, Arup and architects Studio Gang were also conscious of the impact on the local neighbourhood. The unique inverted shape and 'carved' façade is designed to minimise the afternoon shadows cast on the adjacent High Line park, ensuring the building is a good neighbour as well as a great place to work.



Arup's specialist engineering team played an important role in making the building's technically ambitious façade a practical reality, minimising vertical structural elements around the perimeter and maximising floor-to-floor heights. Flat plate cantilevered slabs and sloping columns give the building its unique carved shape, while the faceted façade geometry features sloping diamond and triangular glazing. These are oriented to give access to outdoor terraces and optimise solar exposure, so all the interior spaces have an abundance of natural light.

Our design team also looked at ways to make this complex design efficient to construct. The façade is engineered to optimise installation, using unitised curtain wall construction with bespoke components. These meet the project's design ambitions in terms of aesthetics as well as structural and thermal performance.

Solar Carve is an exciting example of a bold design responding to people's needs for more inspiring work environments that form part of an enhanced urban landscape everyone can enjoy.

“It's extremely gratifying to see our vision for 40 Tenth Avenue come to fruition... the building's iconic design, amazing views and abundant outdoor spaces will benefit the Meatpacking District for many years to come.”

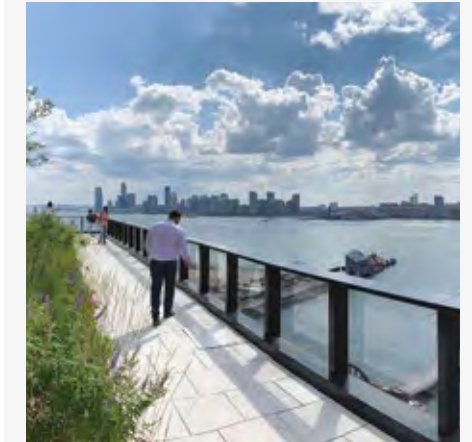
BOBBY CAYRE
CEO Aurora Capital Associates

330%

Amount of annual solar exposure on the High Line relative to allowable building planning requirements

930m²

Roof garden for occupants



FOCCHIGROUP · 2019

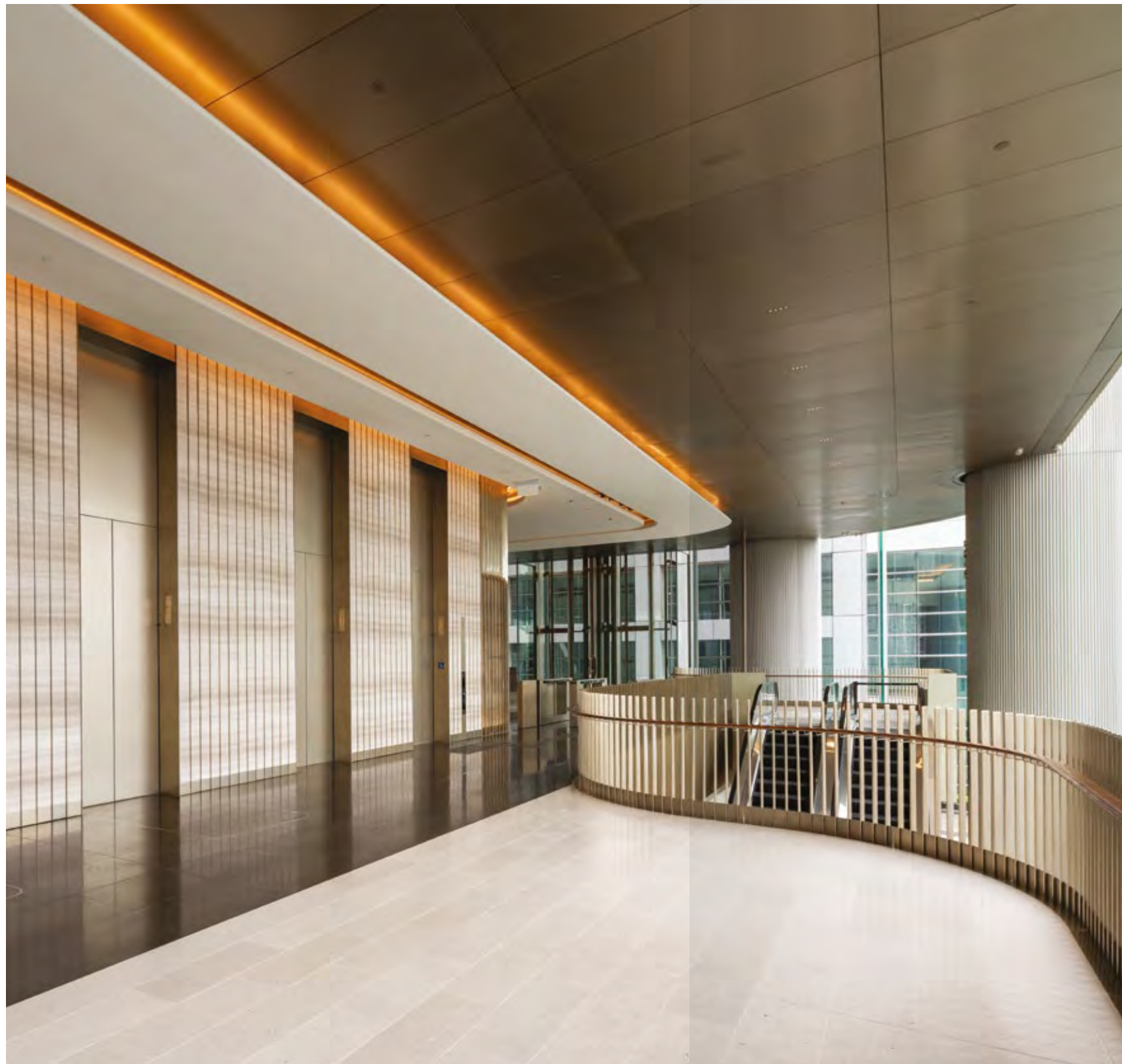
It is finally time to change the view and see how the Big Apple looks from its iconic diamond-shaped building! #solarcarvetower #40tenthavenue #arup



MHLD_NYC · 2019

On the New York Highline – admiring all the great architecture this city has to offer #solarcarve

Neuron Smart Building Technology Hong Kong, China



BUILDINGS THAT THINK FOR THEMSELVES


Around the world, buildings account for almost 40% of energy consumption. That's even more the case in Hong Kong where 90% of the city's electricity is consumed by buildings. In addition, studies show that over 50% of buildings in Hong Kong expose occupants to health issues and discomfort due to poor ventilation and inappropriate indoor temperatures.

To address these important concerns Arup turned to advanced technology, creating Neuron as a 'digital brain for buildings'.

Building automation and energy management systems have been around for some time, but they focus mainly on monitoring and alarm capabilities. Neuron goes much further. It converges data from all of a building's systems within a central analytics platform that can automatically change the way that building operates.

Critically, this technology uses artificial intelligence (AI) and machine learning to analyse and learn from large historical data sets. This enables Neuron to automatically respond to changes in the environment as it constantly looks for opportunities to enhance energy efficiency and improve the indoor environment.

Neuron has already been applied to pilot projects in Hong Kong, including One Taikoo Place, a new triple-A rated, 48-storey office tower developed by Swire Properties. This is now the first AI and data-driven smart building in the city.



Connecting people & places

Across air, rail, road and public spaces our work in transport enables growth and improves lives. From millions of air travellers in Singapore to a single footbridge user in Boston, the goal is always to make journeys safer, easier and more enjoyable for everyone.

JEWEL CHANGI AIRPORT
Singapore



A JEWEL IN CHANGI AIRPORT'S CROWN

The best modern airports serve multiple purposes. At their heart they are a transport hub, connecting people, regions and countries, and fostering economic growth. They are also spaces where passengers want great retail and entertainment experiences.

Singapore's Jewel Changi Airport, a major entertainment and retail complex with links to three terminal buildings, is another example of meeting increasing passenger expectations.

At the heart of the complex is the Rain Vortex, the world's largest indoor waterfall, which cascades 40m from the apex of the building's dome. By day it's an awe-inspiring waterfall, by night it's transformed into a stunning light and sound show.

Arup defined the waterfall's acoustic requirements, and assessed its operational noise impact. We designed the sound system for the water, light and sound show associated with the waterfall, as well as the public address. We were also appointed by the main contractor to provide façade engineering input, building the geometric model prior to development by a specialist contractor. We performed the technical assessment and inspection of the distinctive domed façade during fabrication, production and installation.

Now fully operational, the Rain Vortex is the centrepiece of the whole Jewel complex – making a visit to Changi Airport an unforgettable experience.

Jewel Changi Airport *Singapore*

Cityringen Copenhagen, Denmark

TRANSFORMING CONNECTIVITY ACROSS COPENHAGEN

Copenhagen's new Cityringen metro opened in September 2019, bringing 80% of the city's population to within 600m of a metro or train station. Arup's total design approach put the commuter and community experience at the centre of the design of this 16km metro line.

We led the architectural design and construction planning for the twin-tunnel circular line that runs through the heart of Copenhagen's historic centre. As joint venture partners with COWI and SYSTRA, technical advisor to Metroselskabet (The Copenhagen Metro), we were providing multidisciplinary engineering and advisory services for the new line that integrates with the city's existing high-quality transport infrastructure.

Our architectural principles for the new stations included drawing in natural light underground where possible using large skylights to create a welcoming bright space and mirroring the fabric of the above-ground surroundings to give each station its own identity.

Not only do the skylights enhance the passenger experience, bringing light to platform level and improving energy efficiency, they also act as smoke evacuation vents helping to minimise station footprint. Incorporating elements of colour and materials from the surrounding locality strengthens each station's identity and aids wayfinding. For example, at Trianglen, the high-shine mirrored glass panels reflect the colours of sports fans flocking to the adjacent national stadium, contributing to the lively pre-game atmosphere.

The strategy was to optimise the stations to minimise the impact on the city and the local communities, with the 17 new cut-and-cover stations constructed within existing open spaces in the city. On completion, this has transformed these underused spaces into landscaped community plazas. Using top-down construction helped reduce noise impact and settlement – crucial in a city where older buildings are founded on wooden piled foundations.

Additional technical challenges included tunnelling adjacent to the harbour, constructing Marmorkirken station beside the 19th-century marble church, with Gammel Strand station built under the Slotsholmen canal, which was kept open during construction.

Our work on Copenhagen's transport network is continuing as we bring our technical expertise to the development of the Nordhavn branch off Cityringen. This will create a transport hub for the docklands redevelopment and is due to open in 2020.

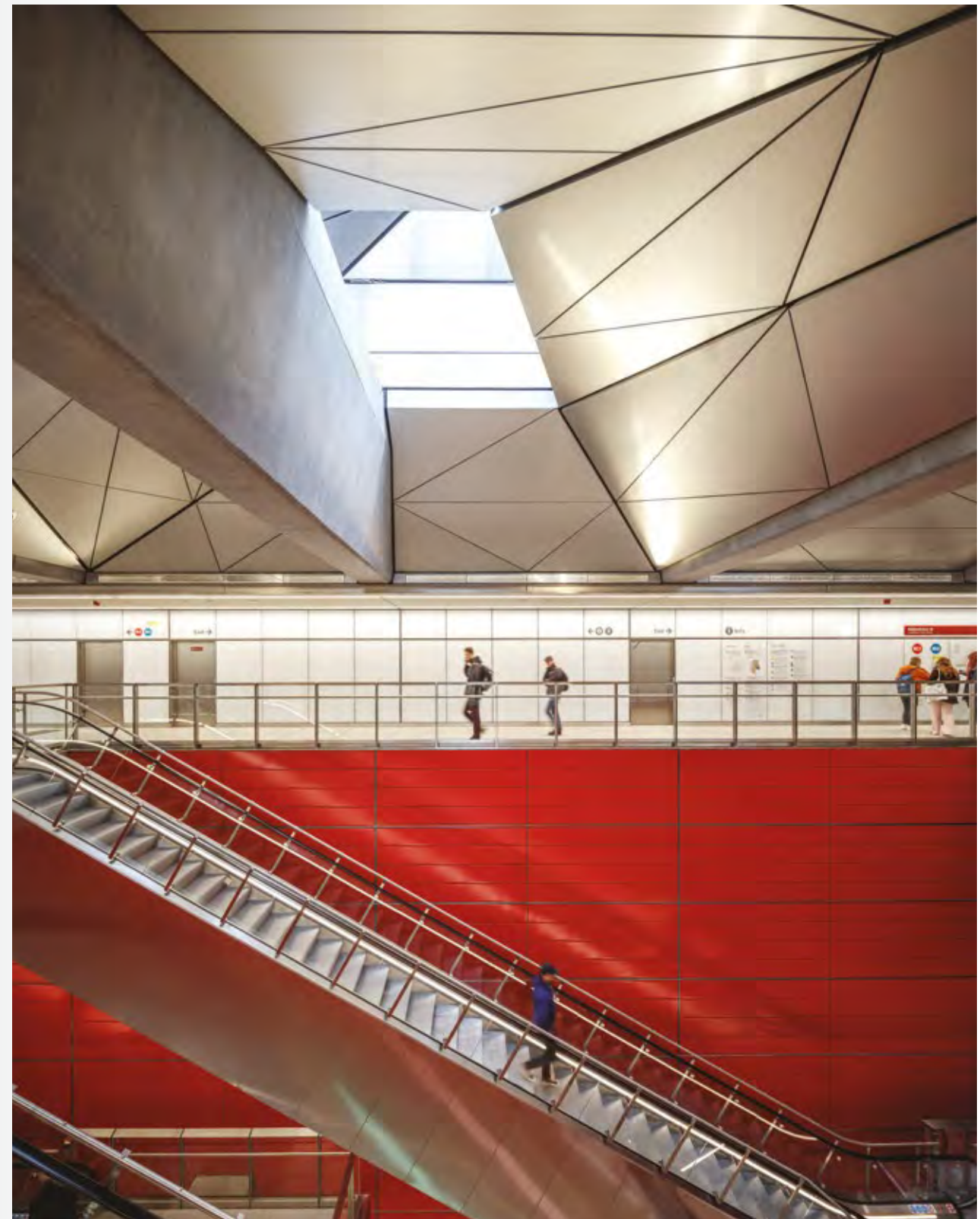
We are also working on designs to extend the underground south to the Sydhavn district. This is due to be completed by 2024.

120 million

Passengers estimated to travel annually

80%

Of the population will live within 600m of a station



Monash Freeway Upgrade Melbourne, Australia



DRIVING GROWTH – IMPROVING SAFETY

The M1 corridor, serving half of Melbourne’s workforce and a third of its residents, is critical to Victoria’s growth and prosperity.

When Transurban appointed Arup as technical advisors to upgrade a section of the corridor called the Monash Freeway, we recognised how important the result would be to the 200,000+ drivers using the road each day, and for the surrounding communities.

The scope of the 44km freeway upgrade is substantial. It included extra traffic lanes, multiple bridge widening projects and the introduction of smart technology to improve traffic flow and driver information. Arup’s expertise included civil engineering, infrastructure design, lighting and intelligent transport solutions, as well as consulting on transport, seismic and bridge engineering.

Arup’s team of over 50 members, from nine offices in six countries, pooled their collective expertise to design a quality freeway, two months ahead of schedule and substantially under budget.

Aside from the economic uplift expected for Victoria, the upgrade is reducing travel times and improving road safety, with a projected 20% reduction in serious injury crashes. New smart technology allows the remote management of lanes – keeping traffic moving more efficiently and improving incident response times.

20%

Reduction in serious injury crashes

2,000

Extra vehicles per hour



INTERCHANGE STATION
West Midlands, UK

High Speed Stations, HS2 London, Birmingham and Leeds, UK

CONNECTING ENGLAND'S MAJOR CITIES

High Speed Two (HS2) is one of the most ambitious infrastructure projects planned for the UK. The proposal is for a new high speed track linking London with Birmingham before splitting to connect with Leeds and Manchester. By putting high speed services on a dedicated line, it will also free up space on the existing network for more local and long-distance commuter services.

An independent review of the project was undertaken in 2019 and its findings will be used to inform the UK Government decisions on next steps.

Arup's work on HS2 has been extensive, with core civil and structural design services complemented by our skills in advanced augmented reality and acoustics. This has enabled planning authorities and residents to understand exactly what HS2 will look and sound like.

Another critical area of our work is the design of three new high speed stations. In London, Arup has led the design with Grimshaw Architects for the proposed transformation of Euston Station.

The second high speed station, the Interchange Station near Solihull, will serve Birmingham Airport and the wider West Midlands area. In addition to the Interchange Station, Arup has been working as HS2's designer for the driverless transport system connecting the station with the airport, Birmingham International Station and the National Exhibition Centre.

Our third high speed station design is for Leeds, where a T-shaped terminus has been envisaged. This would allow full integration of HS2 services with the city's existing station, to form a new combined interchange.

Mactan-Cebu International Airport Lapu-Lapu City, Philippines

LOCAL SOLUTIONS FOR INTERNATIONAL EXPANSION

Like other countries in South East Asia, the Philippines is undergoing significant economic development. That growth is reflected in passenger numbers at Mactan-Cebu International Airport, with totals expected to reach 28.3 million. Our work on the airport aims to meet this demand, with a clear focus on seismic safety, sustainability and use of culturally appropriate design.

In an area of seismic activity, where typhoons are also a risk, passenger and staff safety is paramount. Our team created resilience by designing the terminal as five interconnected, but independently stable, buildings. Using innovative digital modelling, this design approach means each building element will not impact another if a major event occurs.

The new 65,500m² Terminal 2 building has a unique design quality, untypical of most international airports. The undulations of the iconic, large-span roof are reminiscent of waves around Mactan Island. Use of structural timber as the main construction element for this roof – one of the world's largest glue-laminated timber structures – provides both spatial elegance and material warmth. A clear sense of place is created by using furniture and fittings typical of local arts and crafts.

The 18m tall roof has other benefits too. Taking a cue from the vernacular architecture of the tropics, the shape of the structure is a direct response to the local climate. It allows the building's internal temperature to be naturally controlled while maximising the amount of available daylight.

All told, our work on the award-winning Terminal 2 development has been extensive, including aviation and transport planning, airfield engineering design and multidisciplinary engineering services.

The result is a revitalised airport designed to meet the needs of the Philippines' growing economy. Through a carefully considered modular design approach we have also ensured the airport is capable of future expansion in the years to come.

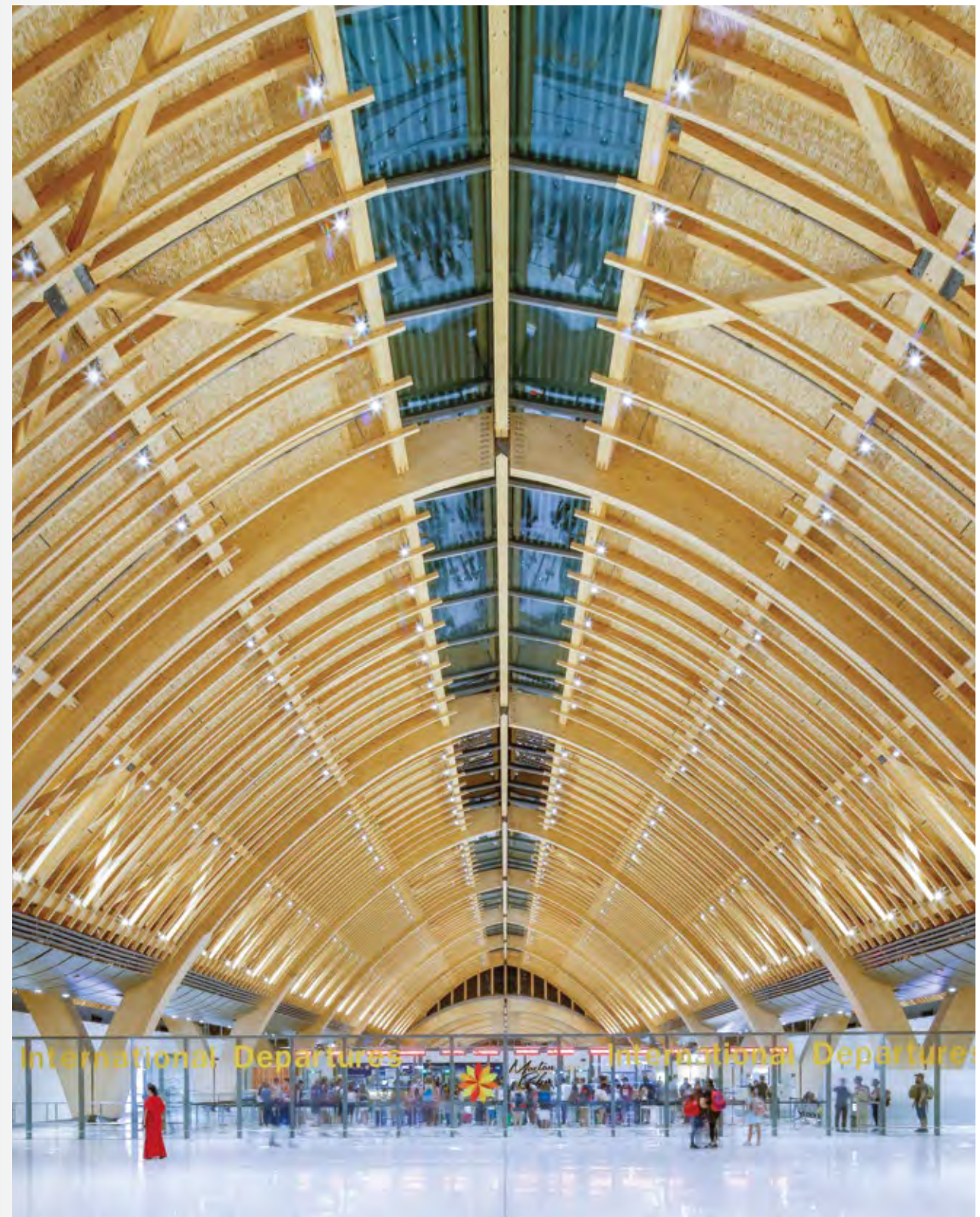
This project was also a precursor to the wider 'Build, Build, Build' programme, aimed at furthering economic growth throughout the Philippines and partly funded by the Asian Development Bank. In support of this programme, Arup is helping the Philippines Government with a strategic transport infrastructure planning review across the rail, aviation, sustainable transport and maritime sectors.

15.8 million

Passengers to be accommodated in phase 1

28.3 million

Passengers to be accommodated in phase 2





ISEC Pedestrian Crossing, Northeastern University *Boston, USA*

STRENGTHENING THE CONNECTION

Bringing together two parts of the campus on opposite sides of a major rail, subway and commuter intersection was a big challenge for Northeastern University in Boston. It was one we were eager to help them meet.

The new Interdisciplinary Science & Engineering Complex (ISEC) Pedestrian Crossing is an example of a technically complex project with design innovation at its core.

The aim was to create an extension of the new ISEC building (a project that Arup completed on campus in 2017) that would be a natural expansion of the landscape. Our team, working with architectural practice Payette, provided bridge, structural, geotechnical, mechanical, electrical and fire safety engineering, and design input for the façade and lighting.

The idea was to design a bridge that connects the student community in a way that's as enjoyable as possible. The design needed to meet strict requirements mandated by the transport authorities while creating a welcoming and secure space for pedestrians.

With this aim in mind, the new curved pedestrian walkway is part bridge and part observation deck – smoothly connecting the main University campus with the new ISEC development.

Vertical steel fins are infilled with laminated glass panels, allowing views of the Boston skyline. The LED lighting is carefully integrated within the structure and benefits from an intelligent control system that limits energy use and optimises brightness. Use of weathering steel – which is inherently corrosion resistant – eliminates the need for future painting.

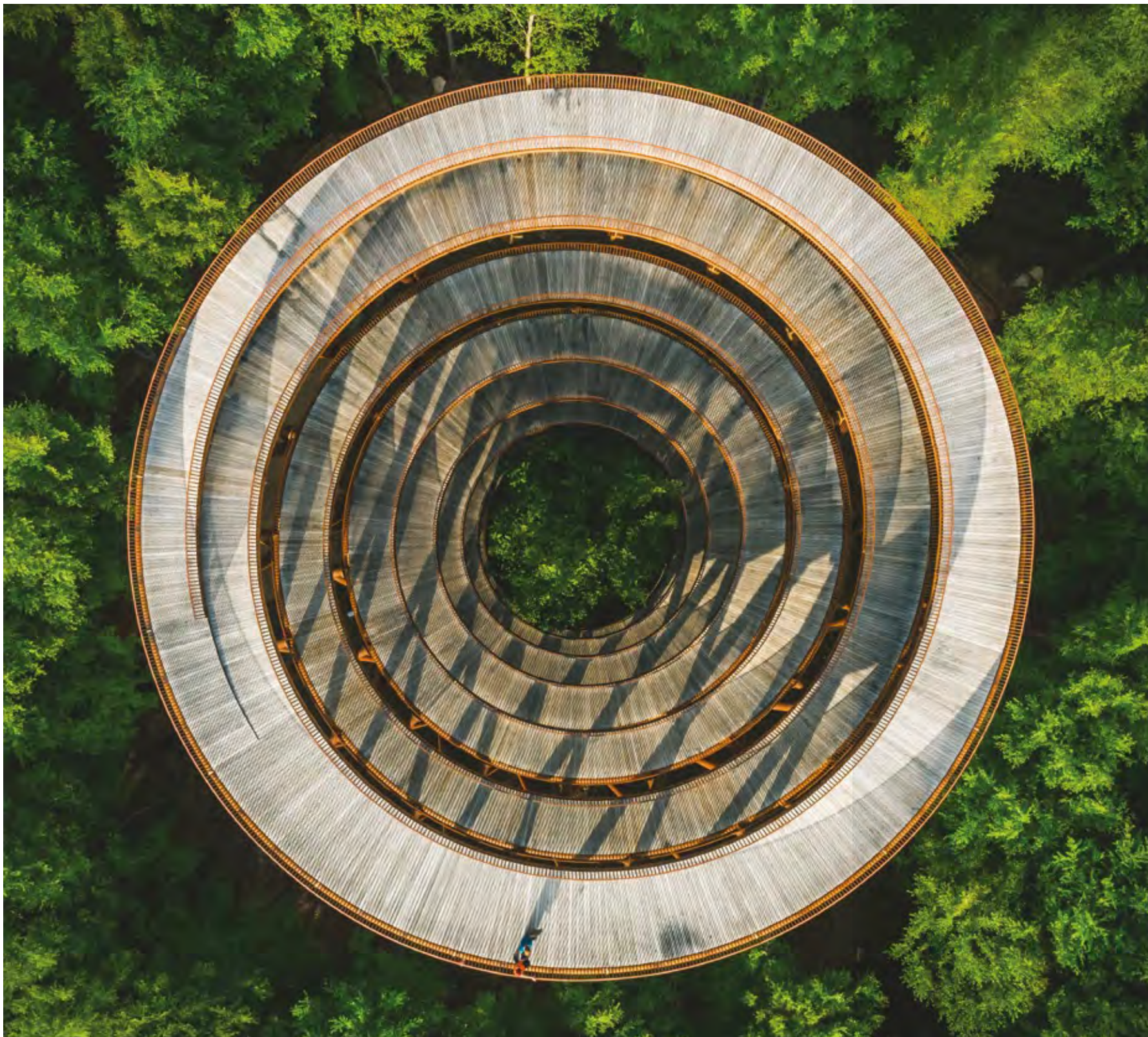
The bridge is already providing benefits beyond the confines of the university campus. In keeping with our broader ambitions to enhance communities wherever we work, the bridge also links two diverse Boston neighbourhoods, helping bring local people together as well as Northeastern's students.



Shaping inspirational spaces

The best facilities expand horizons and feed the soul. From galleries and museums to viewing towers and reverberation chambers, our work this year has seen us meet complex technical challenges to give as many people as possible new, inspiring experiences.

FOREST TOWER, CAMP ADVENTURE
Rønnede, Denmark



Forest Tower, Camp Adventure *Rønnede, Denmark*

ANOTHER LEVEL

Travelling from the forest floor to above the treetops is a wonderful experience for anyone and one that should be enjoyed regardless of physical ability. Meeting this goal and creating something that's both beautiful and sympathetic to the natural environment was our aim with Forest Tower at Camp Adventure in Rønnede, Denmark.

The brief for our team was to engineer a visually arresting observation tower that is sympathetic to its surroundings within a protected forest and offers step-free access to all visitors.

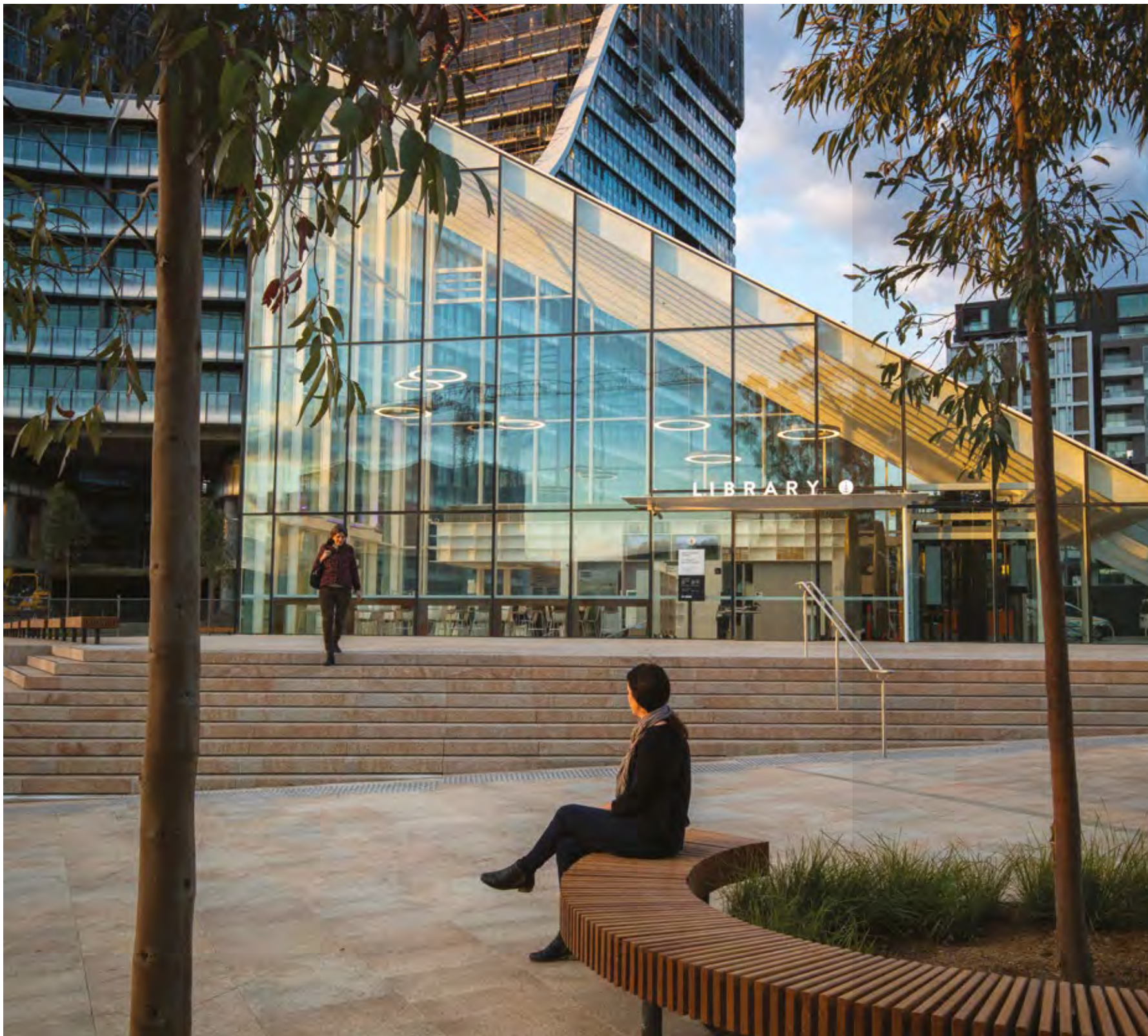
Cutting-edge digital technology enabled the project team to evaluate different parametric design solutions and the impact of each on the overall budget. Geometric modelling techniques brought the whole structure to life, so everyone could visualise the tower in the natural landscape.

The viewing deck of this observation tower, engineered in collaboration with EFFEKT architects, has stunning all-round views of the protected forest canopy. Made of weathered steel and locally sourced oak, the spiralling 45m tower is created from a hyperboloid lattice structure anchoring it into its natural environment.

This shape, with its straight structural steel elements rotated to create an efficient yet visually stunning structure, results in an inherently stiff and efficient frame. The geometry has also been optimised using Arup's modelling software to achieve a ramp inclination suitable for wheelchair access right to the top.

The tower is located at the end of a boardwalk that enables all visitors to access the preserved forest, and culminates in a gentle climb up the spiralling observation tower. The hyperboloid's open design allows the trees to surround each visitor until they reach the 'waist' of the tower, where the vista can be enjoyed from above the forest canopy.

Viewed in one way, the Forest Tower is a stunning structure that mirrors the strength and beauty of the surrounding forest. On another level, it's a brilliant example of accessible design offering everyone a unique experience.



Green Square Library and Plaza *Sydney, Australia*

MAKING THE MOST OF URBAN SPACES

Creating inspiring new facilities for local people is an ambition for many cities. However, with accessible real estate increasingly hard to find, imagination is required to change difficult sites into vibrant spaces.

In Sydney, the challenge for our designers was to create the Green Square Library on a site that was once marshland.

Working with Studio Hollenstein and Stewart Architecture, the project team adapted the competition brief and, by dropping the building below ground, created a flexible open space that can be used for a range of community activities.

Part of the new Green Square town centre, the library's striking glazed entrance pavilion provides a focal point in the plaza.

Allowing high levels of natural light to flood this underground building was an important priority, so 40 large skylights are embedded within the roof. As well as drawing in light, they are illuminated at night providing visual interest and a safer environment at plaza level.



With new hard surfaces part of the plaza scheme, managing water flow from the site was critical. Our civil designers included landscaping and several tree pits to retain water on site before managing its flow into surrounding storm water systems. With the library built below the water table, we also used a multi-barrier approach to manage the risk of water ingress into the building.

Another challenge was the library's open-plan design. With few fixed walls to work with we integrated air ventilation systems within the bookshelves, creating a space that is as open and inspiring for users as possible.

The library and public plaza draws people into the Green Square area. It's a central part of the larger urban regeneration scheme transforming this former industrial zone into a vibrant new community expected to have a population of over 60,000 by 2030.



[@KIMMIN85](#) · 2019
#sydneytravel #greensquarelibrary



[@ARBIEQUE](#) · 2019
Loving Sydney's Green Square library 🍷
#greensquare

11,000

People have moved into Green Square since 2000

40,000

Books, CDs, DVDs, magazines and newspapers

5 star

Sustainability rating from the Green Building Council of Australia

M+ Museum, West Kowloon Cultural District Hong Kong, China



CREATING A CULTURAL HUB

Located at the southern tip of West Kowloon, the 40ha Cultural District is an arts and cultural hub, designed to support the development of Hong Kong's creative economy and evolution as a global tourist destination.

The centre piece of the Cultural District is the M+ Museum, which has seen Arup working in collaboration with architects Herzog & de Meuron and Farrells. One of the most sustainable cultural buildings in East Asia, it is also a project that's provided testing challenges for our engineering team.

The museum sits directly above tunnels for the Airport Express/Tung Chung Line, which runs just 1.5m below ground level. To facilitate construction our designers needed to control the tunnel movements in accordance with strict limits set by Hong Kong's transit and building authorities. Our solution included the use of five 55m mega transfer trusses which prevent the M+ structure loading the tunnels.

Above ground, much of our focus has been on sustainable design, with passive and active strategies minimising use of energy, materials, water and land. A particular feature has been the use of ambient energy sources such as daylight, wind and solar. These improve the museum's microclimate, and reduce both energy demands and operating costs.

The visitor experience M+ offers will be impressive. A large publicly accessible podium space will house a lush, tropical garden, refreshed by the adjacent harbour breeze and irrigated through rainwater harvesting.

The museum benefits from spectacular harbour views and provides 17,000m² of gallery space alongside cinemas, cafés, auditoria and a learning centre. Scheduled to open in 2021, it will form an important part of West Kowloon's transformation into a globally recognised cultural hub.



DESIGNING DUNDEE'S CENTREPIECE

As Scotland's first design museum, V&A Dundee is the centrepiece of a 30-year regeneration of Dundee's historic waterfront. The building's prow projects over the River Tay, with its angular appearance evoking the city's shipbuilding heritage and Scotland's rugged coastline.

At ground level, the museum is arranged as two separate buildings before joining together on the upper floor. This complex arrangement was made possible by our multidisciplinary engineering team using advances in digital technology to progress the design.

Working in collaboration with Japanese architect Kengo Kuma, we designed the building using 3D modelling techniques, with designs communicated through virtual reality software and 3D printing. This approach was vital to successfully creating such a geometrically complex building.

“Working with the engineering capability of Arup made things possible that would not have been possible even a few years ago, creating more natural forms that are even better in reality than when I envisioned the building.”

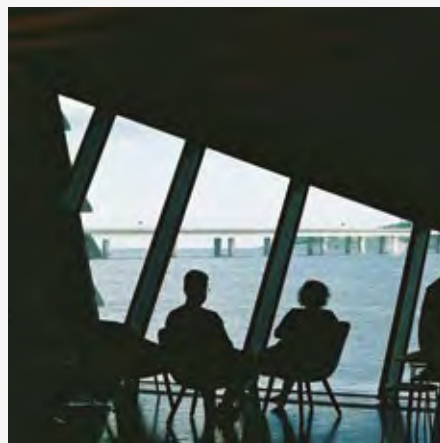
KENGO KUMA

Architect & Professor at the University of Tokyo

V&A Dundee
Dundee, UK



@ CHLOERUNCIMAN · 2019
On our little adventure today Oscar went along to see the @vadundee



@ DBAG11 · 2019
#VADundee #museum #architecture

830,000

Visitors in its first year – 66% above pre-opening estimate

£23 million

Estimated economic impact across Scotland

26,000

People taking part in learning events, talks and workshops in first 12 months of opening

Structurally, the museum is formed from a series of curved and warping concrete walls that lock together with the floors and roof to create a rigid structural shell. We used parametric modelling to optimise the pre-cast concrete panels, while maintaining the random appearance, making their manufacture and transportation more economical. The panels are hung off the structure with a common fixing used for the variations of cladding that give the building its unique shape.

Arup's lighting team also contributed to the museum's award-winning success, with a lighting scheme that enhances the dramatic exterior and enriches the gallery spaces within.

Our low-energy design minimises mechanical cooling in the museum, with ground and air source heat pumps providing direct renewable energy. For a building that is all about showcasing the best in innovation, this application of sustainable design is one of many features that makes V&A Dundee such an inspiring place.



Portable Reverberation Chamber

Björk Cornucopia Tour

SOUND AFFECTS

In her performances – which combine elements of music, live theatre and immersive media – Björk pushes back the boundaries of a live concert experience. As an artist she is interested in exploring the possibilities of the human voice, including how environmental changes alter her performance.

Being at the cutting edge of audio technology has meant Arup's SoundLab is utilised for a huge range of projects where acoustic diagnostics enable optimum sound quality. When world-renowned musician Björk was looking for a portable reverberation chamber for her Cornucopia tour, she came to us for help.

For her latest tour, she wanted to recreate the intimacy of singing solo in a small acoustic space while performing in large international concert venues. She also wanted to avoid any special-effects digital processing. A portable reverberation chamber was the suggested solution, but how do you start to create one of those? Familiar with our innovative SoundLab virtual 3D listening space, Björk asked for our advice.

Our acoustic experts worked with the performer and her creative team designing and developing the final chamber. Björk asked the team to evaluate a variety of shapes and materials and consider all implications of the chamber's form. The acoustics were paramount, but so too were audience sightlines, and the chamber's weight, portability and durability.

The acoustics of various designs were tested over 10 weeks until we achieved the enveloping natural reverberation Björk envisaged. The final design is octagonal to create strong reflections from many directions, with a vaulted ceiling (inspired by medieval chapels) creating a diffused and blended sound quality.

The finished chamber is constructed from a wooden frame coated in a specialised two-component resin, a combination which produces good sound, uses common building materials and can easily be repaired by production staff on tour if required.

“I would like to thank Arup for a divine collaboration: their acousticians helping me design my own private reverb chamber I can travel with. It has been a pleasure!”

BJÖRK
Artist



Space Needle Renovation Seattle, USA



NEW VIEWS AND A NEW LOOK

Enhancing a world famous landmark is always an interesting challenge, particularly when the structure stands 184m tall, but that's exactly what we've done in Seattle.

Visitors to the recently refurbished Space Needle now enjoy an 'elevated experience' with unobstructed 360-degree views across the city skyline. Those with a head for heights can enjoy looking 500ft straight down to ground level through the world's first rotating glass floor.

These new sights are part of the \$100m refresh for Seattle's iconic symbol, which our multidisciplinary engineering team worked on in partnership with architect Olson Kundig.

Built for the 1962 World's Fair, the Space Needle needed a major renovation to enhance the observation experience and prepare the structure for the next 50 years of operation. We provided the behind-the-scenes engineering while the building remained accessible to the public throughout construction.

We designed a new curved stairway that visually and physically connects three public levels, to improve visitor flow and provide those unobstructed views. Structural modifications to the trusses supporting the observation deck allow step-free access to the deck for the first time and new glazed barriers now replace the wall-and-wire fence.

With underfloor services no longer an option due to the glazed floor at the 500ft level, air distribution was coordinated with the sculpted ceiling. Finally, beyond enabling the views, the Arup design focused on bringing the building up to current seismic and energy code standards.

1.3 million

Visitors to the Space
Needle each year

Sustaining the resources we need



Around the world, issues like climate change, population growth and resource scarcity are having an increasingly profound effect.

Our work has seen us improving resilience, pioneering new solutions and helping people from the smallest islands to the biggest cities enjoy the benefits of more sustainable living.

LONDON POWER TUNNELS
London, UK

London Power Tunnels London, UK

COORDINATING THE REWIRE OF LONDON

The London Power Tunnels (LPT) Programme is the biggest upgrade to the UK's national electricity transmission system since its construction in the 1960s.

This £1bn National Grid led project aims to 'rewire the capital' to meet growing electricity demand and to provide a safe and secure electricity supply to London. Over an eight-year period, 32.5km of tunnels will be constructed, 180km of 400kv cables installed, two new substations will be built and there will be major upgrades to a further four substations.

An important part of Arup's role was the central coordination of the project, enabling all its complex elements to work in unison.

During LPT's planning stages we undertook a detailed validation review. Our findings recognised that without a central coordination function there were significant risks to the project's success, with the potential for decisions to be made in the interests of individual projects not the programme as a whole. We recommended establishing a Programme Management Office (PMO) to coordinate LPT's 13 individual projects.

The PMO's primary function is to provide strategic advice to National Grid's senior management and coordinate the complex network of stakeholders across all LPT's project strands. This entailed building strong relationships with contractors and local operations to improve interactions between parties and setting up processes to resolve issues as they arise.

We also instigated a client-only 'site leads' meeting, bringing together decision-makers to resolve higher-level issues. This approach allows the PMO to implement robust controls – with appropriate support, analysis and recommendations – without taking away accountability from the project managers.

Our work on the programme is now complete, and on closing our commission, the programme was on track to meet its schedule and was substantially under the budget sanctioned by the National Grid Board. As a result of this success, many of the tools and processes established on the London Power Tunnels programme are now being included on other major National Grid projects.

“I value the best practice approach Arup has applied to establish the Programme Management Office for the £1bn London Power Tunnels programme. The processes are being actively and successfully used on this major capital programme.”

DAVID LUETCHFORD
Programme Director, National Grid



Hydrogen Production and Refuelling Facility Ports of Auckland, New Zealand



PIONEERING NEW ENERGY

The challenge of transitioning away from undesirable fossil fuels while also maintaining secure, affordable energy requires solutions that are both effective and environmentally responsible. Green hydrogen is a potentially exciting option but, like all emerging technologies, it needs to be tested and then, to fully realise its potential, developed at scale.

The Ports of Auckland Hydrogen Production and Refuelling facility is a groundbreaking project designed to help meet ambitious carbon reduction targets, and has been developed through a partnership between Ports of Auckland, Auckland Council, Auckland Transport and Kiwi Rail. Arup has been engaged by Ports of Auckland to provide technical advice for the project. The plan is to have the new facility for hydrogen fuel cell vehicles up and running at Waitemata Port by mid-2020. This will ultimately support the aim for the Port to be 'zero carbon' by 2040.

Ports of Auckland will fund the construction of a facility which will produce hydrogen from water. The process uses electrolysis to split water into hydrogen (which is then stored for later use) and oxygen, which is released into the air. When the energy is used, the only by-product of the process is water; a virtuous circle. The Port, Auckland Transport and other transport partners will purchase hydrogen fuel cell vehicles for the project.

Beyond the Ports of Auckland, the New Zealand Government is encouraging the generation and use of hydrogen use across New Zealand. There is scope for cars, trucks, trains and ferries to all run on hydrogen, with significant added benefits for the wider community in terms of improved air quality and reduced noise pollution. These benefits are set out in the Arup-authored 'Vision for hydrogen in New Zealand' government green paper, opened for public consultation by Hon Dr Megan Woods, Minister of Energy and Resources, in September 2019.

Subsea Kite Turbine System Holyhead Deep, Wales

FLYING UNDER THE WAVES

As an island nation with over 11,000 miles of coastline, the UK is looking to the sea in search of renewable energy. The question has been how best to harness the tide's enormous potential in a way that's both predictable and affordable.

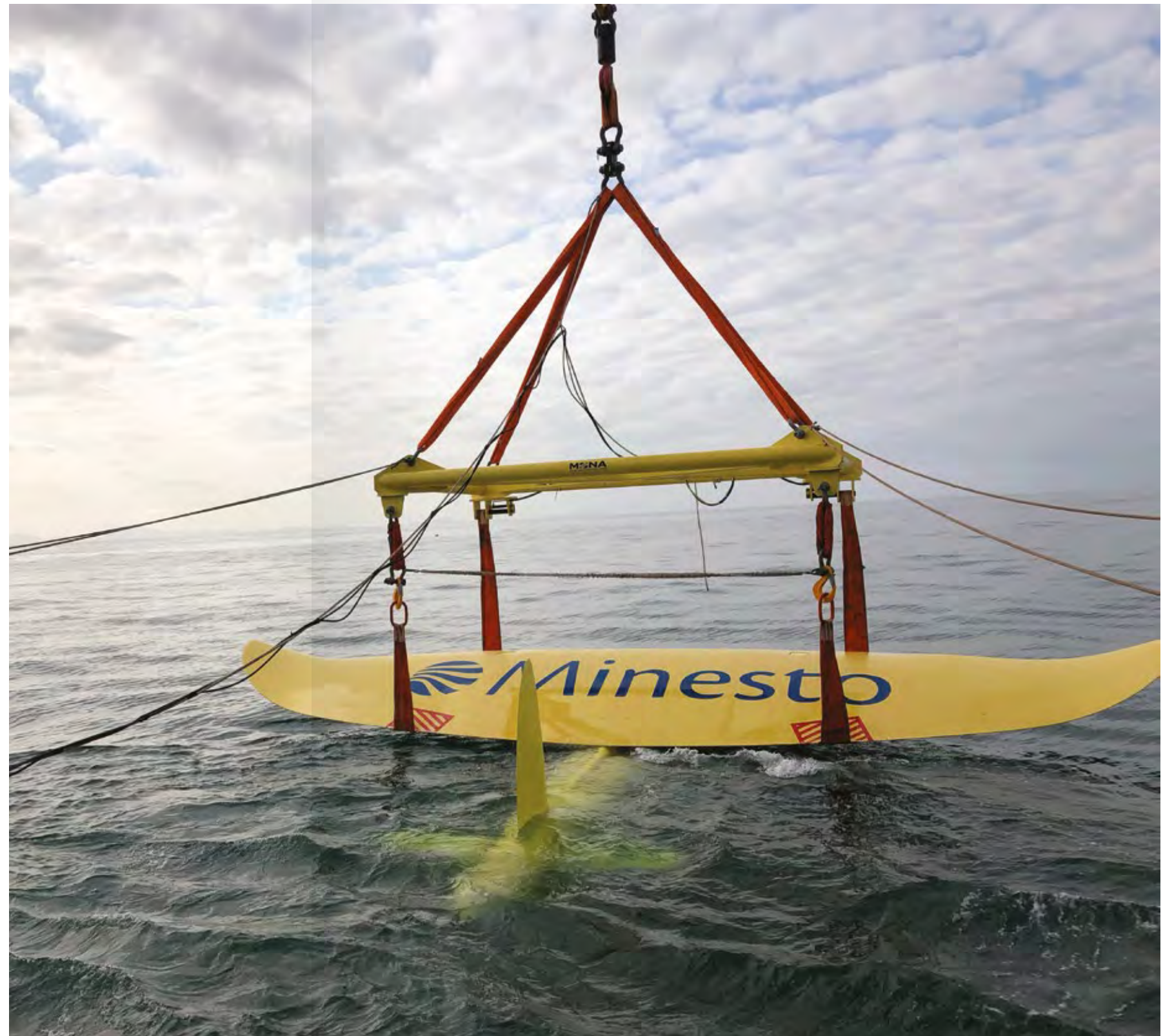
One recent development is the creation of subsea kite turbines. Designed and manufactured by Swedish company Minesto, these winged turbines 'fly' through the water, maximising the energy potential of slower-moving tidal streams.

Our work focused on the kite system's base structures. Arup's energy engineers worked with Minesto to design the first operational turbine, which needed to be floated out to sea and carefully positioned on the seabed.

Utilising digital tools to evaluate the demands of concrete shell structures, we provided design verification and detailing to enable construction to begin. Our naval architects and marine engineers oversaw the construction of the 22m x 13m concrete base in the dry dock, ahead of final siting at the test location at Holyhead Deep, 8km off the Welsh coast.

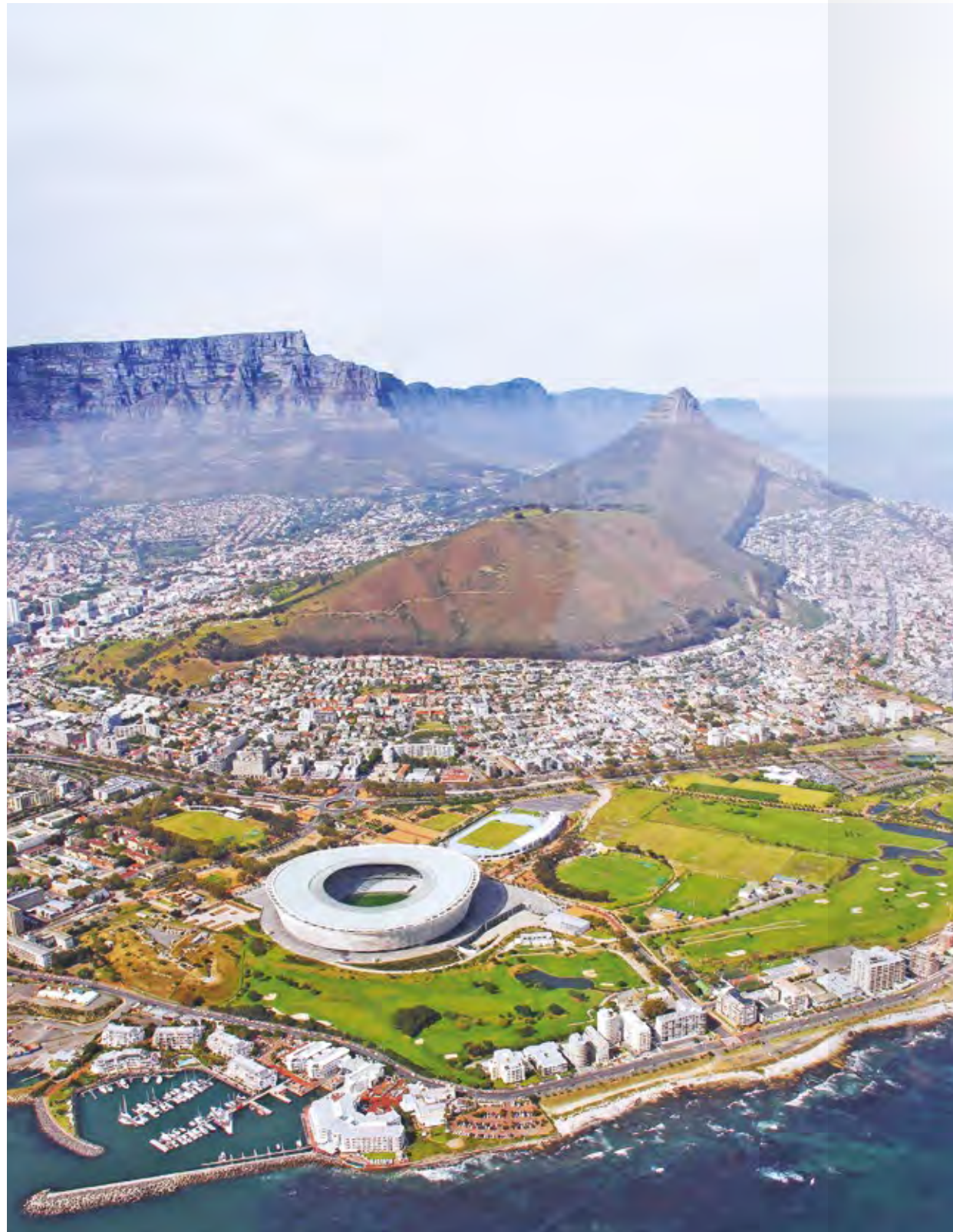
The subsea 500kW kite was successfully tethered to the concrete gravity base structure in mid-2018, the first operational tidal kite of this size anywhere in the world. The kite turbine operates at a depth of approximately 50m, demonstrating Minesto's unique method of converting low-flow tidal streams into predictable, renewable electricity on a commercial scale.

The aim is to deploy a 10MW array of subsea kites, which would be capable of meeting the needs of 8,000 households. Minesto is exploring the possibility of installing arrays with capacities of up to 80MW, raising the prospect that this technology could emerge as a new contributor to the UK's renewable fleet.



City Water Resilience Approach

Global



POSITIVE STEPS TOWARDS A MORE STABLE FUTURE

With cities worldwide expected to grow by an estimated two billion people by 2050, finding ways to provide safe and accessible water services, is more important than ever.

The City Water Resilience Approach was developed by Arup with the Stockholm International Water Institute (SIWI), 100 Resilient Cities and the Organisation for Economic Co-operation and Development (OECD) to help meet this need. Funded by the Resilience Shift and the Rockefeller Foundation, it has seen us working alongside the World Bank, the University of Massachusetts-Amherst and the Alliance for Global Water Adaptation to develop a groundbreaking approach.

It began with a competitive process to select a group of city partners. Eight diverse cities were chosen: Amman, Cape Town, Hull, Manchester, Mexico City, Miami, Rotterdam and Thessaloniki. We worked with these partners to create a global, standardised process to help cities better understand how water impacts their success and would threaten their future. More importantly, it allows them to see the actions they need to take to create future resilience.

We were delighted to share our 'City Characterisation Reports' for the eight partner cities in March 2019. These cities have all taken a significant step forward in recognising how important their relationship with water is and what they need to do to effectively inform future planning and investment decisions. The next stage will see the cities developing detailed action plans that will prepare them for the challenges that lie ahead.

Beyond the eight partner cities, we've created a number of tools to assess cities and their catchments, and identify the most appropriate interventions to enhance resilience. During 2019, the City Water Resilient Assessment Tool was applied in Cape Town and Miami. We plan to introduce this approach to new cities, so they can benefit from everything we have learned and add to the knowledge we are creating.

The threats of flooding or drought are among the most pressing challenges of modern times. We believe the City Water Resilience Approach is a positive step towards a more stable future.

2.2 billion

People around the world lack safe drinking water

207 million

People spend over 30 minutes per round trip to collect water from a safe source

4.2 billion

People lack safe sanitation

Resilience Programme Small Island Developing States

HELPING SMALL ISLANDS BECOME CLIMATE RESILIENT

As a firm we've always used our skills and knowledge to address important challenges. With the global impact of climate change increasingly apparent, we have been working with some of the world's most vulnerable communities to help them create greater resilience.

From the densely populated urban centres of the Philippines, to the atolls and archipelagos of the Caribbean, over 600 million people living on Small Island Developing States (SIDS) are at risk.

Despite some obvious geographical similarities (remote, spatially dispersed and low-lying), SIDS range in size, population, economic strength and access to resources. They face not only natural hazards like cyclones, floods and storm surges, but specific geohazards that can threaten people, assets and economies.

The long-term impacts of climate change such as erratic rainfall and sea-level rises are magnified in SIDS with repercussions on social inclusion, economic development and living conditions.

Our work with SIDS sees our multidisciplinary teams applying diverse skills in systems thinking to address multiple hazards. We currently work across the Pacific, Caribbean and the AIMS (Atlantic, Indian Ocean, Mediterranean and South China Sea) regions, helping communities plan for a more resilient future.

In the Dominican Republic, we worked with national ministries, the United Nations Development Programme and the European Union to develop a country-specific resilience assessment framework. This built on our previous work in urban resilience, including the City Resilience Index and the City Water Resilience Approach.

In Tonga, Samoa and Vanuatu we are working with country governments and the World Bank Global Programme for Safer Schools to strengthen the planning, design, construction and ongoing maintenance of school infrastructure. The aim is to reduce their exposure and vulnerability to natural disasters, and to minimise the impact on students and the community.

600 million

People live on small islands

Over half

The population in Pacific and Caribbean islands lives less than 1.6km from the coast



H7-Hybrid Timber-Concrete Building Münster, Germany



REACHING NEW HEIGHTS

Timber is a carbon-neutral and 100% renewable building material that is increasingly being explored as an alternative option for medium-rise construction. With rising prices for steel and concrete, timber can also provide financial savings.

Building on previous Arup research used in the design for the Lifecycle Tower in Dornbirn in Austria, we applied new approaches to timber construction to the H7 project in the German state of North Rhine-Westphalia.

Named from the German word Holz (timber) and 7 for its seven floors, H7 is the highest timber hybrid building in the state. We collaborated with Andreas Heupel Architects on the project, providing structural engineering, building physics and acoustic design. We also took the project through the critical building permit process when, at the time, the maximum height for timber construction in the state was three storeys.

Having produced an eight-storey prototype building for the Lifecycle Tower, we were able to demonstrate the feasibility and safety of a timber hybrid building and obtain the necessary building permits. A hybrid concrete and timber design, the building's basement car park and ground floor, along with the core, are constructed in concrete. There is also a concrete 'spine' used to distribute the main services along the length of the building.

The upper floors are timber-concrete composite construction with glulam timber used for the columns along the façade. By replacing or supplementing concrete with timber on this project, we were able to realise a saving of one ton of carbon dioxide per cubic metre of timber. Additionally, the timber within the building stores a further ton of CO₂/m³.

Using timber on this project has resulted in a saving of 262 tons of carbon dioxide compared with a conventional reinforced concrete structure. This is enough to fill 262 hot air balloons, each measuring 10m in diameter.

Supporting diverse communities

Shaping a better world means helping people in every corner of the globe improve their lives and enhance their communities. We've done that in a wide range of ways this year – from projects designed to reduce crime or support vulnerable young people, to facilities that will provide new opportunities through sport or education.

UNIVERSITY OF CHICAGO
HONG KONG CAMPUS
Hong Kong, China

University of Chicago Hong Kong Campus Hong Kong, China



MARRYING OLD AND NEW

The University of Chicago Hong Kong Campus (officially known as The Hong Kong Jockey Club University of Chicago Academic Complex and The University of Chicago Francis and Rose Yuen Campus in Hong Kong) is situated on the slopes of Mount Davis, overlooking Victoria Harbour.

Working with Revery Architecture, our role has seen us marrying old and new by repurposing heritage buildings and combining these with contemporary architecture. We've also embedded sustainable design features across the campus, ensuring the environmental expectations of students and faculty are addressed.

Our Hong Kong and Seattle offices provided engineering services – including civil, geotechnical, structural, acoustic, audio-visual, fire safety strategy, building services and sustainability – transforming the site into a modern centre of research, education and collaboration for the University of Chicago.

A new three-storey academic building with curved ribbon profile floats above the site linking with the existing heritage buildings. Built over a steep slope, it is supported on 600mm slender columns up to 17m in height that emulate the surrounding forest of trees. Located just above existing Grade 3 historic buildings, non-percussive mini-piles were used for the building foundations to minimise intrusion. The slope was strengthened through pit-by-pit replacement with cement soil, while soil nails were installed along with masonry retaining walls to further stabilise the slope.

Alterations and extensions were carried out to two of the existing heritage buildings on the site, with elements of significant historic importance retained and protected during the structural modifications.

Our building services team worked with the architect and contractor to enhance environmental performance within both the new and existing buildings. This involved applying current sustainable technology without compromising the older building's historic character.

The sustainable features include a high-performance façade, high-efficiency air conditioning system with heat recovery, reduced lighting power density, daylight responsive controls, increased fresh air flow rate and a demand-driven fresh air supply system.

1930s

Period building was initially built by the British Army to defend the western side of Victoria Harbour

75 years

Age of the Delonix regia tree which provides a focal point for the building

Women's Safer City Project Honiara, Solomon Islands

DESIGNING OUT CRIME

A chance workshop meeting in London inspired two Arup members to combine forces and devise a groundbreaking security design approach.

Alice Vincent from our Resilience, Security and Risk team in Singapore and Luke Millar from Arup International Development in Sydney wanted to see safer spaces in refugee camps and informal settlements for children and young women. But it was Plan International Australia who asked us to pioneer the approach for their existing 'Safer Cities for Girls' initiative.

Honiara in the Solomon Islands became the first in-practice application thanks to funding from Plan International Australia and Arup Community Engagement. We worked closely with a group of 16 to 31 year olds, allowing us to understand how young women felt excluded from the decision-making processes around their safety in their own city.

It saw the women themselves working alongside representatives from city government and NGOs, to identify problems and find workable solutions. This inclusive, empowering approach put the young women at the heart of the decision-making process.

Main outputs included recommendations for a community-developed and -owned street lighting plan, a mixed-use police and sports building that creates a shared space for former antagonists, and a management model for the city Botanical Gardens that includes playgrounds and leisure areas, to help to crowd out night-time drinking.

This project is the first of its kind to combine the security design approach (Crime Prevention through Environmental Design) with the Child-Centred Urban Resilience Framework developed by Arup and the NGO, Plan International Australia.

These two methodologies meshed really well with the recommendations that came from the young women themselves. We see real potential in using this approach for more child-centred urban development work in the future.

“This work takes proven urban safety design principles and puts them to work for young women whose points of view on accessing the city safely should be front and centre, but often aren't.”

LUKE MILLAR

Project Manager, Arup International Development





WaterUp Programme *Rajasthan, India and Global*

KEEPING WATER FLOWING

With mobile digital technology becoming more widely available across the developing world, the 'WaterUp' programme puts knowledge and skills directly in the hands of those most affected by the impacts of climate change and water scarcity.

Alongside the charity Flow Partnership, we are working on a global initiative that is using educational videos to enable rural communities around the world to utilise traditional and sustainable water management techniques. The ultimate aim of WaterUp is to 'upskill' communities so that they are empowered to reap the rewards of improved water management from a health and economic viewpoint.

Initial development has been based in the Rajasthan region of India, which covers 10% of the country's area and yet has only 1% of India's water resources. As part of our community engagement programme, working with the Flow Partnership, we have been investigating, recording and modelling successful examples of traditional rainwater-harvesting techniques. As part of the project, the charity and their partners have already implemented two new water management programmes, using earthen check dams and overflow structures, that will benefit 30,000 people.

Informed by this research, the language-neutral and universally applicable educational videos will include graphical representations, animations and films. They will be disseminated around the world through a global 'Water School' app, giving communities direct access to the knowledge they need. Research has shown that this kind of community-based, 'bottom-up' approach to water management is one of the most effective and robust ways to keep water flowing.



MOKLI Help Finder Berlin, Germany

BLOCKCHAIN FUNDING FOR HOMELESS YOUNGSTERS

Accessing basic services like food, shelter or medical services is difficult for all homeless people. That's even more the case for children and teenagers who rarely have access to banks or credits cards. Our work with Berlin-based charity KARUNA Sozialgenossenschaft uses innovative technology to unlock the problem.

With research showing that the vast majority of homeless young people have access to smartphone technology, the MOKLI Help Finder app allows them to quickly locate the basic services they need.

The planned roll-out of a digital wallet feature for MOKLI significantly expands the scope of the project.

This new feature will match cash donations earmarked for specific purposes – such as meals, hot showers or a bed at a local hostel – with users in need, giving them access to these services without needing a credit card or a bank account.

As digital consultants, our role on the project has been to utilise Blockchain technology to ensure that these cashless transactions operate in a secure and transparent way. This involves recording them in digital ledgers and storing them in a decentralised network.

As one of the winning projects from the 2018 Google.org Impact Challenge, the development of the Blockchain donation functionality has been financed through the Challenge prize money.

The digital wallet feature is expected to launch at the start of 2020. With economic inclusion the key to social inclusion, KARUNA and Arup hope it will make a big difference to the lives of young people in Berlin, providing secure, easy-to-access funding for the basic services they urgently need.

37,000

Young people in Germany have no permanent residence

3,500

Emergency aid facilities are offered throughout Germany using the app

80%

Of young homeless who flee from their home environment take their smartphone with them

Flood Resilient Shelter Guide

Pakistan

SHAPING BETTER SHELTERS

Since 2010, extreme flooding in southern Pakistan has affected 35 million people – damaging or destroying 2.5 million homes. In response, aid organisations have built 200,000 shelters for the very poorest households, while many other people have built their own.

With limited technical guidance and extremely tight budgets, it was unclear which designs and materials provided the best mix of robustness and affordability. Our research for the International Organization for Migration Pakistan and the UK Department for International Development has answered this question.

To assess and improve shelter design, we carried out 800 field surveys, conducted desk studies and tested 24 full-scale wall panels. Our study focused on flood resilience and structural performance. We considered factors like cost, comfort, lighting levels, carbon footprint and environmental impact.

We found shelters made from earth mixed with a little Portland cement or lime can resist low-to-medium scale flooding at least as well as those made of fired bricks.

This ‘improved earth’ option also has 85% less embodied carbon than a brick shelter, and doesn’t require trees to be cut down to fuel the brick kilns. What’s more, it’s cheaper and can be easily repaired by the homeowner.

Using these findings, we created the evidence-based Pakistan Shelter Guide with best-practice shelter designs and a decision-making tool. This guide empowers agencies and communities to construct sustainable, flood-resilient shelters in a part of the world where natural disasters are arriving with increasing frequency.

200,000

Shelters built to house the poorest households

35 million

People affected by flooding in southern Pakistan

2.5 million

Homes destroyed





Pan American & Parapan Games *Lima, Peru*

SHAPING A LASTING LEGACY

In 2019, over 6,500 athletes from 41 countries competed in the Pan American and Parapan American Games in Lima, Peru. The Games were the largest sporting event ever held in the country.

Hosting the Games offered Peru a huge opportunity to transform its sports infrastructure, and accelerate economic growth and societal changes – promoting equality, respect and sound governance.

As a core member of the UK Delivery Team, Arup's work on the project was based on a unique government-to-government agreement. This saw over 50 Arup specialists from around the world work on planning and supporting the design of 14 new sports venues and the Athletes' Village.

Working closely with Pattern Architects and others, we ensured all the venues were optimised for use during and after the games. From using computational fluid dynamics to design a wind barrier that helps sprinters achieve their best times, to advising on a curved stand to enhance audience engagement, the goal throughout was to create world-class facilities for participants and spectators alike.

Across the whole project Arup's goal was to create both world-class sports facilities and longer-term benefits for Lima's citizens. Our extensive experience working on the London 2012 Summer Olympics and Paralympics was crucial in this respect, particularly with the complex task of managing multiple stakeholders working within immovable timeframes.

Sharing the lessons learned from London also ensured a confident approach towards long-term legacy. The use of digital design technology was an important factor here, allowing venues to be constructed with an in-built flexibility and ensuring their long-term viability.

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