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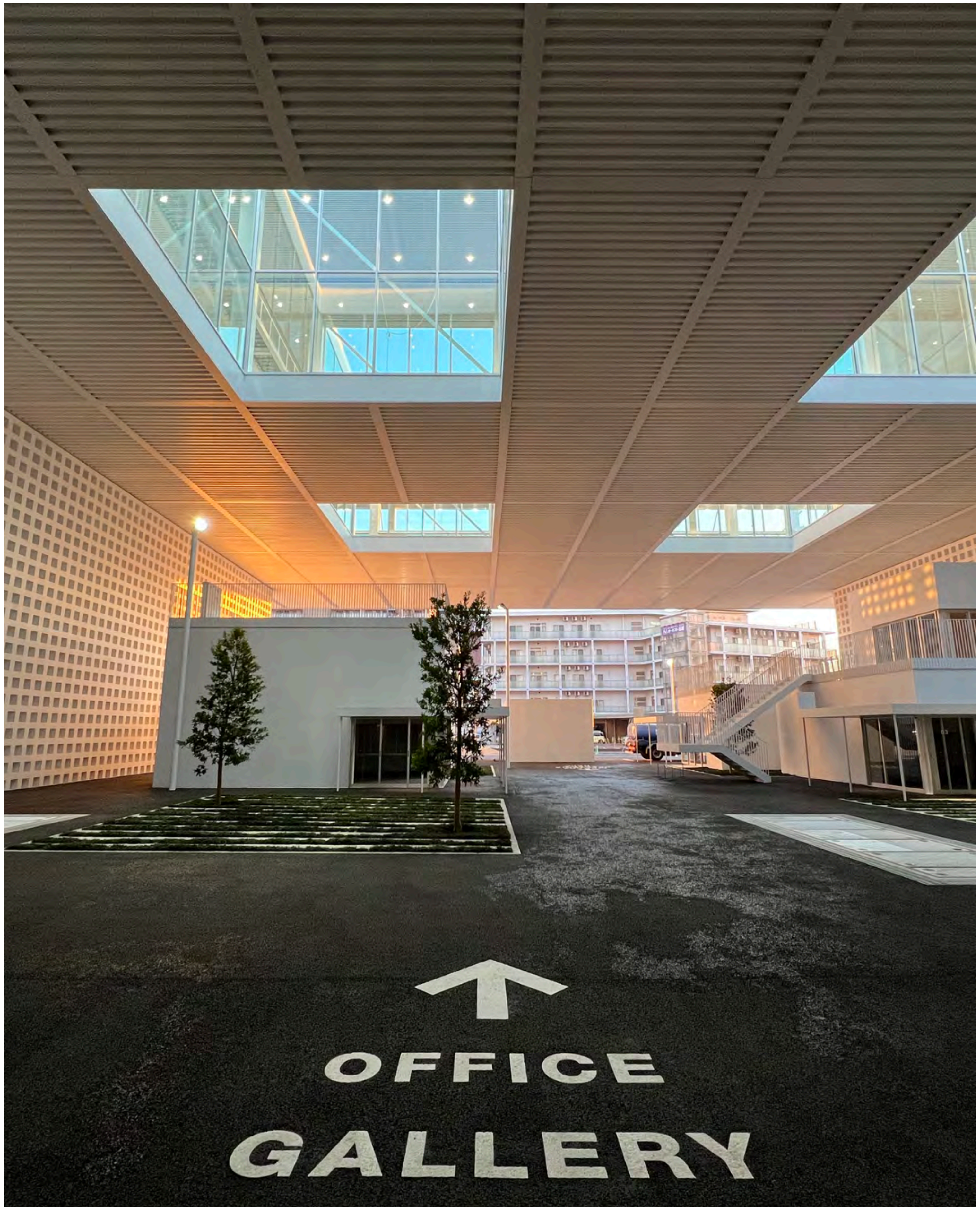
ARUP

The Arup Journal



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1.

Integrating innovative bridge design with cultural expression

Innovative level crossing removal that creates activated community space enhanced by the Aboriginal connection to the Country

Authors Duncan Butterworth, Ross McConnell, Liam O'Donohue, Orr Niv Shallev

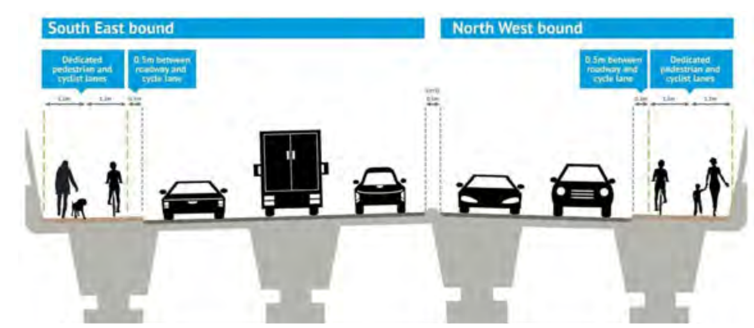
Ovingham is a busy, primarily residential suburb in the outer fringe of Adelaide's central business district. On Torrens Road, at the intersection with rail lines near Ovingham railway station, boom gates were previously required to stop traffic when trains approached. Every day more than 21,000 vehicles passed through the level crossing, facilitating three rail lines – two for the Gawler suburban commuter railway line and one for Adelaide-Melbourne freight rail services. When the traffic flow was stopped to allow trains to pass through, this caused congestion and increased travel times for drivers, cyclists and pedestrians. The goal of the Ovingham Level Crossing Grade Separation was to improve safety, give commuters more certainty about travel times and improve community connectivity.

The solution identified was to raise Torrens Road above the rail lines and remove the road-rail level crossing. The Karrarendi Yerta (the new Torrens Road bridge) is the centrepiece of the development, providing motorists with a continuous route through the area, with the removal of the level crossing improving safety for all. The bridge provides three southeast-bound lanes and two in the opposite direction, with a combined pedestrian and cycle path on both sides of the bridge.

Crucially, the plans also offered a welcome opportunity to provide new open public space below the elevated road created by the 178m long x 25m wide bridge. Local residents are now benefiting from improved community facilities and connections between local streets. The project team worked closely with the local community on the Karrarendi Yerta Kadla (plaza area), which showcases Aboriginal art and culture and incorporates green spaces, recreation areas and connected pathways, with lighting considerations for day and night use. Opened in February 2023, it provides approximately 30,000m^2 of new public space.

1: The Karrarendi Yerta (the new Torrens Road bridge) has reduced traffic congestion and created a striking new community space

2: The bridge carries five lanes of traffic and has dedicated paths for pedestrians and cyclists



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The Public Transport Projects Alliance – Ovingham (PTPAO) delivering the removal of the level crossing comprised the Department for Infrastructure and Transport, designers Arup and Mott MacDonald, and contractor McConnell Dowell. The site was identified in the State Government's *Keeping Metro Traffic Moving* report as a priority location to address road congestion. The A$231m project, which included an upgrade to Ovingham station and adjacent cycling facilities, was jointly funded by the Australian and South Australian governments on a 50:50 basis.

Setting a new standard for Aboriginal co-design and cultural expression outcomes for infrastructure developments in South Australia and beyond, the project is a testament to the power of cross-disciplinary collaboration. Arup played an instrumental role as part of the Alliance, which has improved transport efficiency in Ovingham and embedded local indigenous stories, knowledge and art throughout the site's striking community space – now a destination in its own right.

Bridge building benefiting the wider community

Before construction of the bridge, boom gates dropped down at Torrens Road for approximately 12 minutes per hour in peak periods to allow train passage. The Karrarendi Yerta now allows motorists to bypass the rail intersection, regardless of train movements below, easing congestion and cutting travel times. Residents who were previously divided by transport infrastructure are reconnected, allowing for freer movement through the precinct, strengthening ties with the community. Upgrades to the adjacent Ovingham railway station have also improved the commuter experience. The redeveloped station, Karrarendi Yerta and new public spaces benefit the local community and commuters passing through the area.

Innovative bridge design creates more public space

The Karrarendi Yerta bridge design uses fewer supporting piers than a traditional precast concrete girder bridge, enabling the creation of additional open areas underneath for community space. By using continuous steel composite girders, rather than precast concrete super-T girders, the PTPAO achieved much longer spans between piers than typical precast construction. This avoided the need for piers to be located near the railway tracks. During construction, this removed the requirement to pile within the rail corridor.

The design negated the need for large deflection walls (typically 1.5m in height) which are required to protect piers within 10m of the rail. This also provided better sight lines for trains and better visibility for pedestrians and cyclists using the space, encouraging passive surveillance and thereby improving the perception of safety in the space. The longer spans, with a maximum length of 58m, increased bridge construction costs, but savings were made by de-risking other elements of the works. By reducing the number of piers, the design minimised underground service relocations, including alleviating the need to relocate a 300mm-diameter high-pressure gas transmission line and a 50-year-old, 1.45m-diameter wastewater main. The Alliance carried out a detailed safety management study, in collaboration with the gas asset owner, resulting in a design solution that didn't require any relocation or protection works for the gas main.


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3: The project has delivered a flexible and adaptable public space that facilitates community connection


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4: Before the bridge was built, traffic on the busy Torrens Road was held at level crossing gates whenever trains approached Ovingham station

In total, 89 continuous flight auger piles were installed for the works to support the bridge, ramps and retaining walls. The 900mm-diameter reinforced concrete pile depth ranged from 15m to 24m below ground. The girders supporting the bridge deck were fabricated by South Australian company Bowhill Engineering, using steel sourced from Australian businesses BlueScope and Infrabuild. The girder weight ranged between 35 and 102 tonnes, with the 16 girder segments weighing approximately 1,330 tonnes in total. The differing segment weights were largely driven by pier locations, with the design seeking to eliminate the need for temporary works and the relocation of underground services. The girders were installed directly onto temporary supports that were affixed to the permanent concrete piers, eliminating the need for temporary works structures within the rail corridor. There was a high degree of coordination and collaboration with Australian Rail Track Corporation and concurrent rail projects, including the installation of girders in coordination with the Gawler Rail Electrification Project, which was being undertaken at the same time as the level crossing removal.

Torrens Road, along with the intersecting Churchill Road, are important transport corridors for Adelaide, providing additional routes to the north and northwest of the city. The solution had to minimise traffic disruption, balanced with ensuring the safe operation of the roads and intersection. Due to the constrained nature of the area, there was minimal space for establishing temporary traffic corridors to allow the complete construction of the bridge; as such, traffic staging and switches were required to build elements in the existing road corridor. To minimise the interruption to live road and rail traffic and improve safety during construction, the team focused on limiting the number of traffic switches to the bare minimum, while maximising the offline construction area, with the new alignment constructed to the north of the existing alignment. This fully integrated temporary and permanent design solution increased overall safety and productivity, while minimising rail and road traffic interruption.

In the initial phase of the works, 2.5km of water mains were relocated and lowered to allow the construction of the bridge structure and associated road works. In addition, 11km of conduits were installed for the lighting, traffic,


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5: The design uses fewer supporting piers than a traditional precast concrete girder bridge

6: The girders were installed directly onto temporary supports affixed to the permanent concrete piers

7: The project required a high degree of coordination and collaboration with Australian Rail Track Corporation


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train signals and CCTV design, with installation of the conduits under the railway completed by drilling and underboring the conduits, removing the interface between the construction team and the railway. This method enabled the works to be completed without any track occupations or delays to trains.

Indigenous culture, inclusive urban design

At the project's outset, the PTPAO and partners at Aboriginal Urban Design, a local Aboriginal-owned and managed business, established the Kaurna Reference Group to prioritise First Nations collaboration in the design. The group included Kaurna people, Traditional Owners of the Adelaide Region, and they provided an invaluable voice regarding the inclusion of culture in the design. The Reference Group, including landscape architects ASPECT Studios and Cox Architecture, met for several workshops at which the narrative and cultural expression elements were co-designed.

The consultation was an open discussion where stories were told and translated into urban design elements in the bridge, the plaza and the surrounding precinct. A clear and unanimous goal for all involved was to communicate to commuters using the Karrarendi Yerta that the land is Kaurna land. The Karrarendi Yerta official name is in recognition of the trade route used by the Kaurna people between the Tarndanyangga (Adelaide) and Yerta Bulti (Port Adelaide) regions for thousands of years.

Another consideration was that the overpass removal had initially been planned 40 years ago, but when the works did not go ahead previously, the land was planted. Woodland had developed in the intervening years, and the necessary removal of these trees was seen as a significant loss by the community. The team developed a solution to mitigate this loss through enhancing the area to provide a higher level of amenity, with a significant cultural heritage element.

Under the bridge, the large open space provides room for communal activity and connects to the wider precinct, which showcases Aboriginal artistic elements depicting numerous Dreamtime stories. The design acknowledges Kaurna's local story of the interconnectivity between land and sky. The elements included the expression of complex ideas such as the mirroring of the Karrawirra Parri (Torrens River) in the Wodliparri (Hut River or Milky Way). Some of the story elements were embedded in the structure of the bridge and in the paving of the plaza, while others were left to artists to convey through public art. The project involved the commission of mural works on the abutments, the bridge piers and the railway station equipment room, and four sculptural artworks, with several contributing to the telling of the Kaurna stories through thematic or conceptual alignment. Two large-scale murals were commissioned for the concrete abutment walls beneath the Karrarendi Yerta. Six artists worked collectively to depict their interpretations of the Tindo (Sun) and Kakirra (Moon) in the story. Three sets of four bridge piers were commissioned as murals and allowed local artists to interpret the story through their own eyes. The ambitious programme of public art procurement provided support and employment opportunities for emerging and established Aboriginal artists. Young Kaurna artists were apprenticed, enabling them to develop

8: Torrens Road and the intersecting Churchill Road are important transport corridors for Adelaide

9: Consultation with Kaurna people helped turn Aboriginal stories into design elements for the bridge and surrounding areas


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10: The large open space under the bridge provides room for communal activity

11: Elements of the local Aboriginal story of the interconnectivity between land and sky were woven into the bridge design

skills in the execution of large-scale public artworks during the project.

The work was undertaken in a strong spirit of reconciliation and working together to build lasting community relationships. Developing trust between various entities was crucial to the project's success. The relationships established between groups and the standard that was set regarding Aboriginal cultural expression and storytelling embody a process of reconciliation. This collaborative and respectful approach represents a benchmark in design which reaches far beyond the Ovingham Level Crossing Grade Separation.

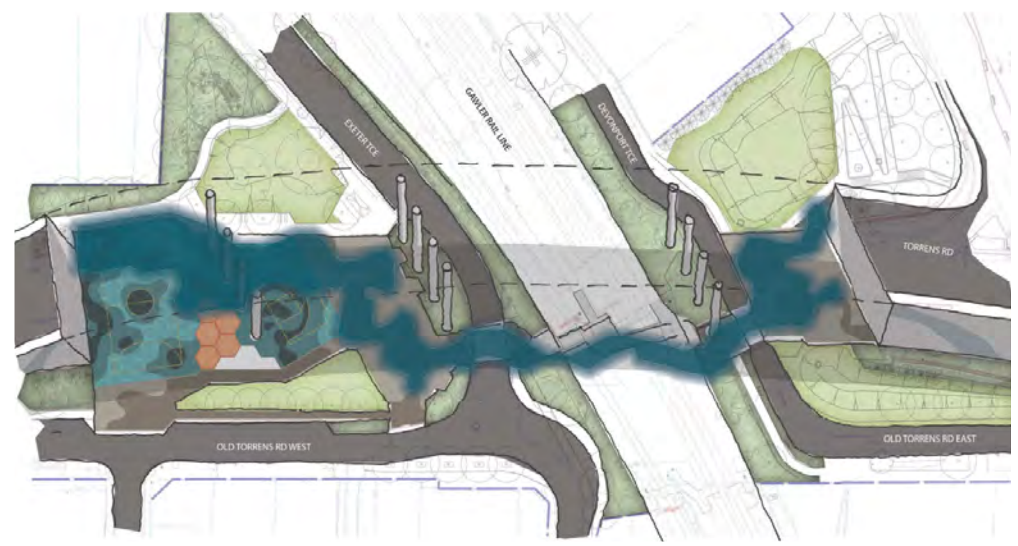
The project team also worked closely with the two local councils – City of Prospect and City of Charles Sturt – to provide the sports and recreation facilities identified by the councils as required, including a futsal court and half-basketball court, and to support their local recreation and community needs. The site office and laydown areas that were used during construction are being converted into public parks, which will provide the community with additional open green space once the works are complete.

Lighting the way

The Alliance's lighting designers worked in close collaboration with Cox Architecture to achieve a balance between feature and functional lighting that is reliable and can be safely maintained. The design consisted of two key elements: lighting of pathways and sporting courts, and uplighting to the structural elements. The design needed to ensure it met the requirements of the local lighting standard for public spaces and pedestrian areas (AS/NZS 1158) while not over-lighting the space; creating an energy-efficient, open and welcoming public realm in the pathways throughout the space and designated sporting courts; and minimising the number of lighting poles where possible.

Lighting plays a crucial role in the built environment in influencing perceptions of safety in public places. Brighter lights do not necessarily make people feel safer, as they can create high-contrast areas and stark, darker zones that deter people at night. At Ovingham, by focusing on the main pathways and gathering areas, and supplementing with uplighting of vertical surfaces, the project created a welcoming atmosphere which is not over-lit. The result is also more energy-efficient and minimises maintenance requirements.

The feature uplighting elements to the public realm provide illumination to the abutment walls and bridge piers, which feature various layers of Aboriginal cultural expression, including the murals. They also spill over to light the bridge soffit and integrated urban design elements mounted to it. Lighting to these vertical surfaces emphasises and highlights the artworks and stories embedded in the murals. It also provides soft reflected light throughout the space, creating a low-glare and visually comfortable environment, reducing dark spots and enhancing the perception of safety, in line with night-time activation principles. Sports surface lighting was provided and set on a separate timer with manual activation, which allows it to be turned off when not in use, saving energy and allowing the more subtle lighting strategy to take precedence.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Transport infrastructure upgrade

The opportunity to upgrade the adjacent Ovingham station was taken during the construction works. The main feature of the upgrade was to ensure the station achieved compliance with the Disability Discrimination Act 1992. The works also included the installation of new shelters and improved platform access, lighting and CCTV coverage. In addition, the Gawler Greenway, a bikeway running from Adelaide's CBD Park Lands to the 'interchange' of three major cycle paths at the eastern end of the Port River Expressway, was extended. There were new pedestrian pathways, modifications to the pedestrian crossings of the railway line, and the provision of a new bike lane along Torrens Road.

Oviform sewer

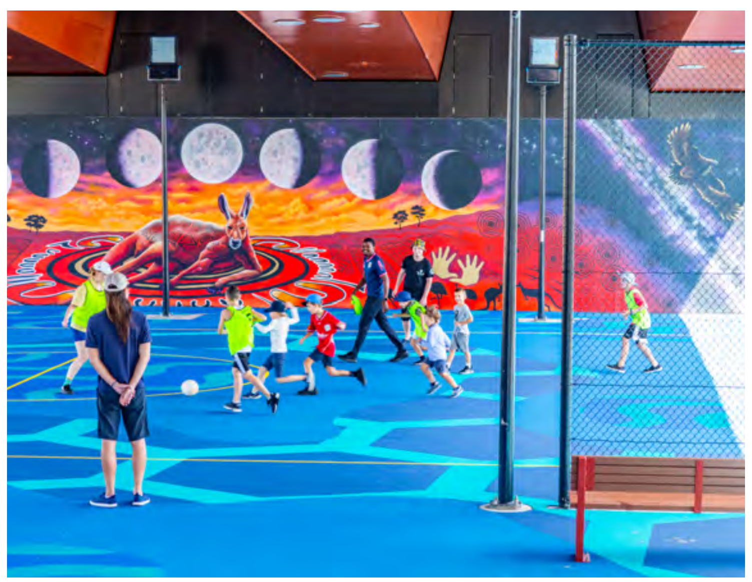
A major constraint for the project was the presence of an existing oviform sewer main constructed in the 1880s, its condition largely unknown. The sewer is a critical piece of infrastructure for the local area, feeding into a 1.45m-diameter sewer main that takes wastewater from the new Royal Adelaide Hospital. The sewer runs perpendicular to the bridge alignment, effectively dissecting the construction site. Load limitations surrounding the sewer main meant that the major plant required on site, including piling rigs and the 750-tonne crane for installation of the bridge girders, had to be disassembled, remobilised around the sewer, and rebuilt either side of it.

The team identified that two of the outriggers of the crane would need to be positioned immediately adjacent to the 3m exclusion zone of the main. A temporary works design solution was implemented involving concrete augered piles being used to transfer load away from the sewer. This facilitated more efficient cranage of the girders, delivering programme benefits and reduced disruption.

Sustainable materials

This was the first Department for Infrastructure and Transport project to use recycled plastic atoms to replace virgin aggregate in concrete. The Alliance team worked with Seels Technology and other stakeholders to successfully employ the Toberite plastic product. In total, 110m^3 of concrete was used to construct the centre median in Torrens Road. The use of the 100% recycled atoms diverted 2.5 tonnes of plastic from landfill, and the atoms can be recycled again at the end of the median's lifecycle.

For the subbase layer for road construction, 10% recycled crushed glass was used, diverting glass too small to be recycled away from landfill. In total, 66 tonnes of municipal glass waste was diverted from landfill.



14.

12: The feature uplighting elements provide illumination to the abutment walls and bridge piers

13: Ovingham station was upgraded during the construction works

14: The identity and character of the precinct has been enhanced by new sport and recreation facilities

15: The project has delivered more efficient transport and a flexible and adaptable open space for residents

Improving safety and the public realm

The Ovingham Level Crossing Grade Separation has improved safety and efficiency for road traffic, rail services, cyclists and pedestrians. The successful removal of the level crossing has increased reliability for buses using Torrens Road. The public realm improvements contribute to a stronger connected community, which was previously divided by transport infrastructure.

Delivery of the project required an innovative design solution and a creative construction approach to minimise disruption to the road and rail networks, nearby residents, and businesses, while maintaining an operational railway and station, and safe access and egress from the station during construction.

The project has delivered a flexible and adaptable public space that facilitates community connection; enriches the identity and character of the precinct with night-time activation and sport and recreation facilities; and showcases extensive Aboriginal Cultural Expression elements.

Authors

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Project credits

Client Department for Infrastructure and Transport

Alliance partners Australian Government, McConnell Dowell, Mott MacDonald

Collaborators Cox Architecture, ASPECT Studios, GT Planning, Aboriginal Urban Design

Bridge, geotechnical, façade, highway, rail and structural engineering, flood risk management, infrastructure design, lighting design and transport consulting, public art procurement

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A practical guide to sustainable development

Exploring opportunities for Malaysia to foster clean growth

Author Devni Acharya, Murali Ram

Malaysia is emerging as a promising arena for clean growth and sustainable development in a world increasingly focused on sustainability. The concept of clean growth relates to growing national income while reducing greenhouse gas (GHG) emissions and is a challenge for Malaysia where, over the past 30 years, the gross domestic product (GDP) has increased by 389%, while GHG emissions have risen by 289% in the same period. By 2030, Malaysia aims to achieve its target of reducing carbon intensity against GDP by 45% compared with 2005 levels, and to achieve an average of 4.7% real GDP growth annually at constant prices.

The UK is one of more than 30 countries across the globe to have demonstrated that it is possible to decarbonise while growing national income. The country's Climate Change Act, carbon budgets and multisector decarbonisation plans, among other measures, have helped the UK to meet its emission reduction targets while growing its GDP. This experience is useful for Malaysia, showing how to stagger policies, develop industry standards and collaborate with the private sector. A crucial aspect of this is how people and companies innovate to respond to these targets.

Malaysia is looking to benefit from that experience, with the UK providing support by matching the needs of Malaysia with strengths from the UK to help smooth the path to decoupling economic growth from carbon emissions. The UK Foreign, Commonwealth & Development Office (FCDO) has worked with the Malaysian public and private sectors over recent years to help accelerate climate action in the country. The FCDO and the Department for Business and Trade commissioned Arup to develop the Clean Growth Handbook Malaysia to build on these initiatives and help reshape the landscape of sustainable development in the country, supporting Malaysia's long-term aspiration to be a net zero country.


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1: The UK FCDO has worked with the Malaysian public and private sectors to help accelerate climate action in Malaysia

2: By 2030, the nation aims to reduce carbon intensity against GDP by 45% compared with 2005 levels

3: Power contributes to around 42% of total GHG emissions in Malaysia

Critical sectors for clean growth

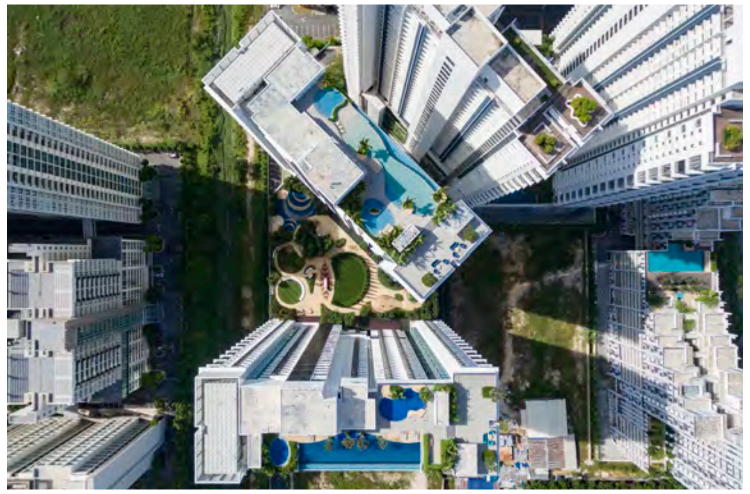
The handbook highlights opportunities to introduce or scale clean growth in Malaysia. It identifies 40 collaboration prospects between Malaysia and the UK across four priority sectors – power, transport, buildings and manufacturing. These sectors have the ability to enact large-scale change, as they are those with higher GHG emissions and gross added value contributions to the economy.

Power contributes to around 42% of total GHG emissions in Malaysia, making it a clear priority area for the country's clean growth journey. Of this, close to one third of emissions can be attributed to buildings, based on global data. With Malaysia targeting an urbanisation rate increase from 75% in 2020 to 85% by 2040, this is likely to see an increase in the number of buildings developed to accommodate additional live, work and play capacity.

Approximately 21% of total GHG emissions comes from transportation fuel use, with only 20% of journeys made by public transport. With Malaysia's

The project in numbers:

- **4** priority sectors identified – power, transport, buildings and manufacturing
- **40** clean growth collaboration opportunities
- **46** stakeholders engaged in Malaysia and the UK to gain market insights and identify clean growth opportunities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4: Malaysia can look to the UK's regulations and guidelines for low-carbon architecture and to help deliver low-carbon buildings

5: Currently, only 20% of journeys in the country are made by public transport

5.

population set to increase by 11% by 2030 and expected growth in passenger car sales, this shows the importance of focusing on transport as a clean growth priority. Finally, 19% of emissions comes from fuel use and the non-energy use of fossil fuels in industrial activities.

This is the first time four economic sectors have been examined in a single document at the national level in regard to clean growth. The handbook provides market overviews, before listing clean growth opportunities for Malaysia within each sector that UK companies could support.

Growth opportunities

To develop clean growth, an ecosystem of stakeholders within and outside the country is required to collaborate. Arup engaged 46 stakeholders in Malaysia and the UK to gain market insights on Malaysia's clean growth. The handbook identifies opportunities across each of the four priority sectors for developing clean growth and collaboration opportunities with UK companies that have built up considerable expertise which Malaysian organisations can draw on, identifying collaboration opportunities between the two countries.

Power: Malaysia is retiring commercially unviable coal power plants, while the UK is retrofitting coal plants for renewable energy opportunities. Together, both countries can collaborate on retrofitting coal power plants for renewable and transition fuels. There is also the prospect of producing green hydrogen and implementing carbon capture, usage and storage (CCUS) projects that could make use of the knowledge created from the UK's experience.

Transport: The UK brings experience in integrated transport planning to support the uptake of public transport use, the development of vehicle charging networks and innovations in multifuel stations to power hydrogen and electric logistics fleets.

Buildings: Green building certification is gaining traction due to increasing tenant demands and available tax incentives. The concept of zero-energy buildings is on the rise, as is the adoption of low-carbon building materials as embodied carbon becomes an increased focus. Malaysia can look to the UK's regulations and guidelines for low-carbon architecture and to help deliver low-carbon buildings.

Manufacturing: Increased energy costs are driving manufacturers to adopt more energy-efficiency measures. The UK brings experience in industrial thermal energy audits and developing circular business models that can be tapped into to provide improvements in this area.

Clean growth enablers

Using the enabling framework from Arup's Global Green Economy report, the handbook identifies nine enablers of clean growth in Malaysia across three categories – directive, business case and implementation enablers.

The directive enablers set the direction and basis for interoperability, covering governance, policy and regulation, and standards; business case enablers that support the commercial case for adapting clean growth cover data and infrastructure, market incentives, and technology and innovation; and implementation enablers that include practical elements required for successful delivery cover funding and financing, capabilities and collaboration.

The handbook lays out key findings related to each enabler which can support the uptake of clean growth in Malaysia:

1. Governance: Develop an integrated transport planning strategy that clearly lays out the roles and responsibilities of different stakeholders. Adopt an approach to national and local governance for implementing district cooling systems.


6.

6: Collaboration opportunities include the adoption of resilient transport asset management strategies for rail

7: Malaysia can learn from the UK's experience in the development of vehicle charging networks

8: Buildings are one of the four priority sectors identified in the handbook

2. Policies and regulations: Develop a unified clean or green growth strategy to set a shared ambition for sectors and stakeholders across the country. Develop an integrated transport planning strategy that integrates public, private, active and autonomous modes. Update the Uniform Building by-laws to include minimum low-carbon requirements, and develop and introduce Environmental Product Declaration requirements to the market.

3. Standards: Establish stringent standards on heavy or polluting vehicles entering cities or low-emission zones and integration of embodied carbon in green building certifications.

4. Data and infrastructure: Develop and introduce battery energy storage systems (BESS) before 2030 to accelerate renewable energy adoption and support local government in active mobility planning.

5. Market incentives: Introduce additional funding for green technology and develop an equitable electricity tariff framework.

6. Technology and innovation: Adopt technology to mitigate the effect of renewable energy fluctuations on grid stability and adopt industrialised building systems and timber construction.

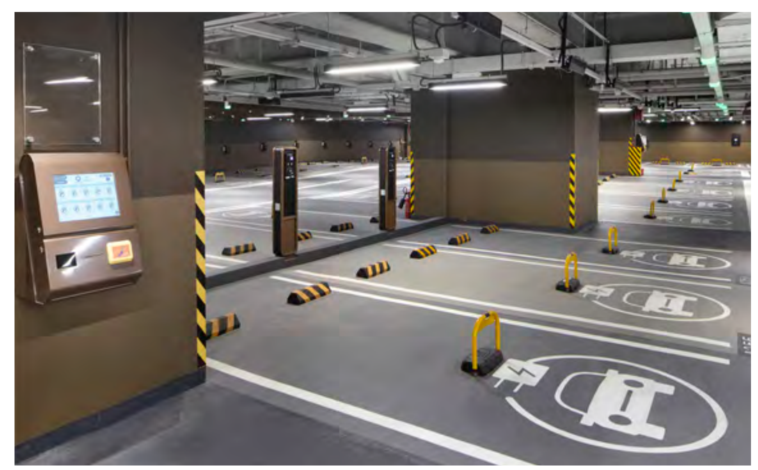
7. Funding and financing: Develop a net zero carbon funding and financing strategy for identified low-carbon implementation measures.

8. Capabilities: Develop knowledge-sharing initiatives for maintenance of renewable energy facilities. Introduce training on carbon emissions modelling to support states and cities developing emissions reduction targets, on whole-life carbon assessments for buildings, and on product life cycle assessments and environmental product declarations. Develop higher education syllabus to include holistic transport planning.

9. Collaboration: Develop a strategy to support the low-carbon start-up ecosystem.

Sector collaboration opportunities were also set out in the handbook based on each relevant priority sector across five emerging themes of UK-Malaysia collaboration:

(i) Scaling infrastructure development: Develop integrated solar photovoltaic and battery. Diversify bioenergy plants with different biomass waste feedstocks.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9: The Clean Growth Handbook envisions an economy characterised by reduced carbon emissions, increased energy efficiency and enhanced environmental stewardship

Roll out electric buses and develop associated charging infrastructure. Develop green port infrastructure. Introduce end-to-end renewable energy implementation for industrial sites.

(ii) Design and engineering services: Support the technical and financial feasibility of small-scale hydropower projects. Adopt grid stability measures including BESS, hydrogen and pumped hydro. Adopt resilient transport asset management strategies for rail. Design industrial parks that adopt industrial symbiosis and design and implement industrial CCUS clusters.

(iii) Setting governance and standards: Develop standards and governance around hydrogen and carbon storage. Update building regulations and guidelines in relation to zero-energy buildings and low-carbon construction. Develop integrated transport plans and logistics strategies at both national and local levels. Implement district energy systems.

(iv) Adopting technology and innovation: Commercialise BESS technology. Retrofit fossil fuel power plants and gas network for renewable and transition fuels. Scale biofuel and sustainable aviation fuel production from globally recognised sustainable sources. Adopt low-carbon construction materials and construction techniques. Develop fourth industrial revolution technologies for energy efficiency, renewable energy and circular economy adoption. Support circular economy opportunities for automotive components, electrical and electronic products, and plastic packaging.

(v) Tools and data platforms: Evidence-based identification of industrial energy-efficiency measures.

Proactive steps

As the world grapples with the urgent need for decarbonisation, Malaysia stands as a shining example of a nation that is taking proactive steps to address this challenge. The handbook can be used to identify where there is market demand for international support, to seek out organisations to collaborate with across Malaysia and the UK, and to understand some key considerations for UK companies starting to work in Malaysia.

At the heart of the handbook is a vision that transcends short-term economic gains and aspires to create a more equitable, sustainable and prosperous future for all Malaysians. It envisions an economy characterised by reduced carbon emissions, increased energy efficiency and enhanced environmental stewardship. It seeks to work in harmony with Malaysia's abundant natural resources and use human capital to drive innovation, create new industries and foster economic resilience.

In the years ahead, the successful implementation of the Clean Growth Handbook looks set to yield economic, environmental and social dividends, setting a path towards a prosperous and sustainable future for all Malaysians.

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Client United Kingdom Foreign, Commonwealth & Development Office, and Department for Business and Trade

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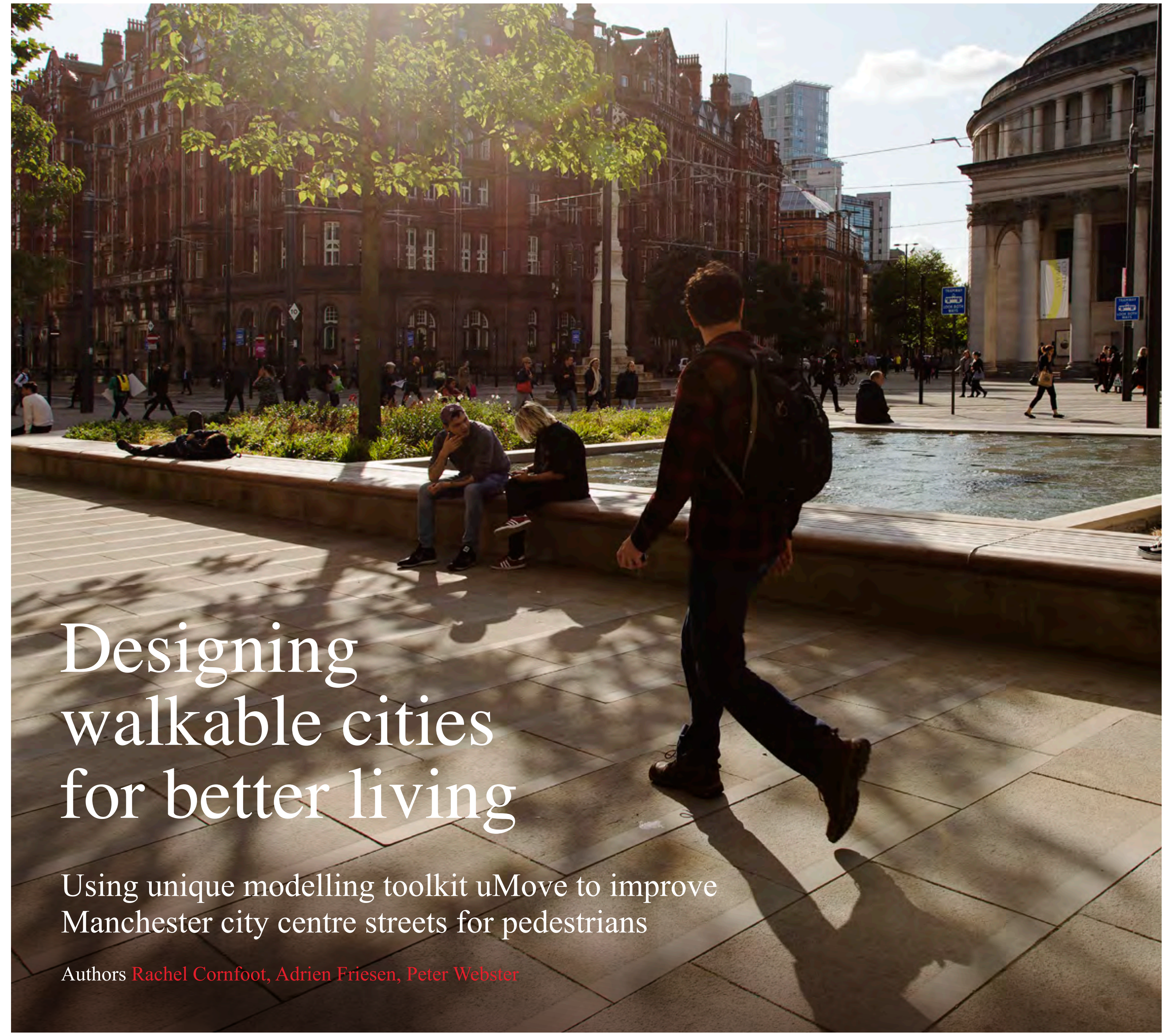


Designing walkable cities for better living

Using unique modelling toolkit uMove to improve Manchester city centre streets for pedestrians

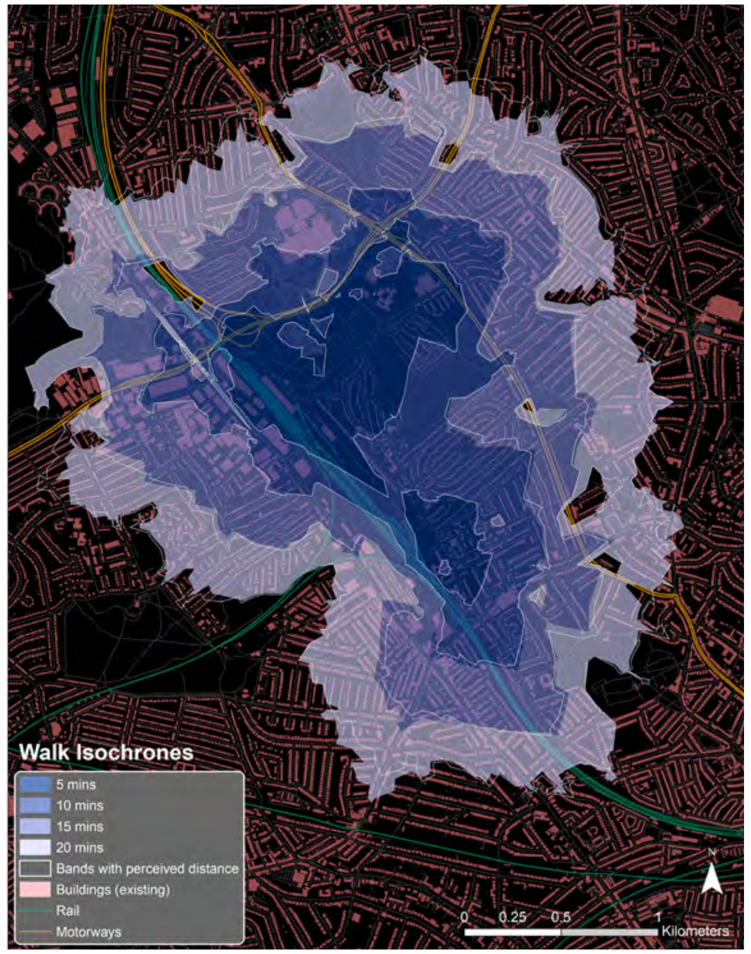
Authors Rachel Cornfoot, Adrien Friesen, Peter Webster

1.

1: Manchester City Council commissioned Arup to review the city centre's walking and wheeling network

The growth of many of the UK's major cities creates challenges for city planners, including the requirement to create an inclusive network of streets and spaces in which pedestrians can move safely and comfortably. In order for the UK to be able to meet its net zero targets, reduce inequalities and air pollution, and improve quality of life for all, cities must focus on improving walking and wheeling routes (for prams, wheelchairs, children's scooters, etc.) so that people are enabled to use active travel on a daily basis.

Manchester city centre has a rapidly growing population and is one of the UK's major employment, retail and entertainment hubs, which puts ever-increasing demand on the pedestrian infrastructure. The existing walking and wheeling network needs targeted



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2: Example uMove output showing how real-distance isochrones can be compared with perceived-distance isochrones, highlighting directions of higher walk quality

3: Demand generation is calculated using factors such as building footprints, height and land-use/activity rate

and transformational improvements to make it more accessible, inclusive and sustainable, for both existing and future needs. Manchester City Council commissioned Arup to review the city centre's walking and wheeling network and develop a pipeline of proposed interventions to improve the walking environment. This is part of the city's aim to achieve a 70% increase in the number of journeys into the centre using active modes of transport by 2040.

But how do you create a city centre that encourages walking? Unfortunately, many of our cities' streets and spaces are designed to prioritise motor vehicles, creating environments that can be unpleasant for people walking and wheeling. Footways are frequently too narrow, have poor surface quality and often have vehicles parked across them. It is becoming more common for improvements to be put in place for people cycling in cities across the world, but we must also ensure that urban streets are accessible for people walking and wheeling. How can we ensure that our cities are safe, inclusive and attractive for everyone to walk and wheel?

3.

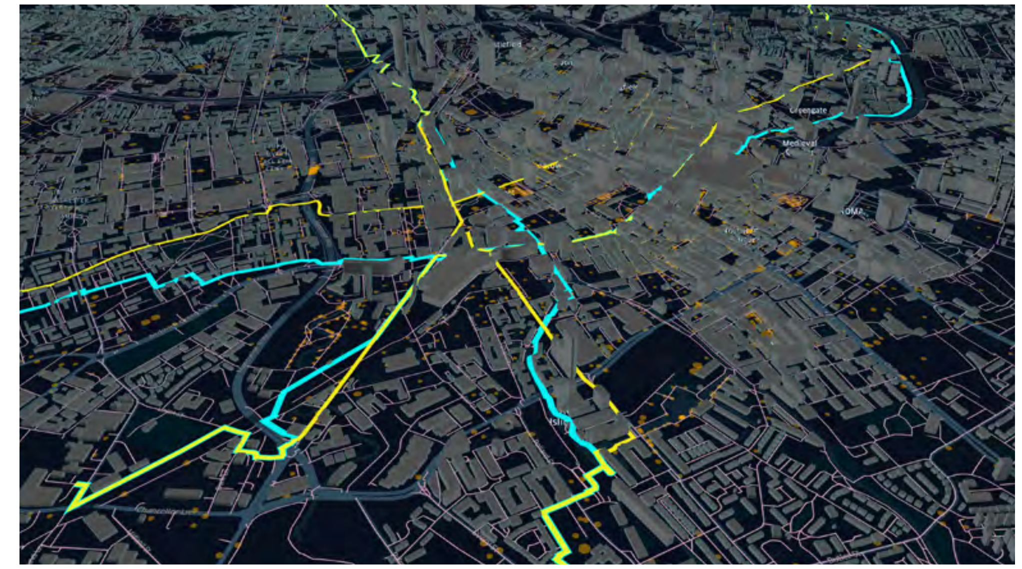
Using uMove, Arup's in-house people movement modelling toolkit, which enables evidence-based prioritisation of locations to improve the pedestrian environment, the team reviewed Manchester city centre's walking network. Local knowledge and the design expertise of staff in Arup's Manchester office were then focused on the priority locations to identify interventions to make walking and wheeling more attractive by improving safety, comfort and inclusivity on each street.

Modelling scale and resolution

uMove is an urban movement modelling toolkit that uses open-source datasets with global coverage, enabling rapid analysis of large areas. One of uMove's greatest strengths is its ability to automatically generate walk quality factors, providing insights as to where people are most likely to be walking and how those parts of the network vary in quality.

For the Manchester City Centre Walkability Study, the client needed a fast, evidence-based and objective method to prioritise the locations within the city centre where improvements to the pedestrian network would have the greatest impact. uMove enabled Arup to undertake this analysis in a matter of days in an efficient and consistent way, providing the client with the evidence base to justify the selected locations for intervention.

The toolkit considers a number of characteristics that are drawn from the data, allowing predictions as to which areas will be relatively busier than others. Arup's People Movement team have a range of tools they can apply depending on the scale of the area and purpose of the study. uMove sits at the upper end of this scale as a network analysis tool. It can be used as a standalone tool or as a precursor to more detailed modelling with such tools as MassMotion. uMove takes a human-centric approach to determine route choices. It considers alternative routes that people might choose to take, based on their preferences for environments with higher walking quality. It considers factors such as distance, steepness, straightness, green spaces, route quality and land-use attractiveness.



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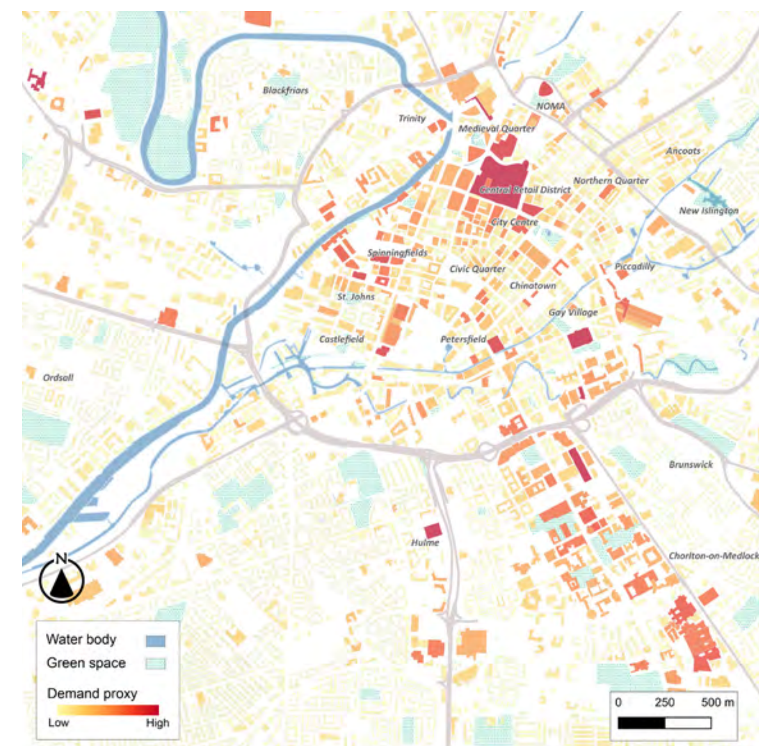
It allows a user to select a focus area by typing in a place name or pair of latitude-longitude coordinates, along with a buffered distance around that specific point. The tool then employs an application programming interface (API) to collect the required data from Open Street Map (OSM) and gets to work building and analysing the network. The tool generates a perceived distance for each link, which represents how a pedestrian would rank one option over another, with pedestrians opting to use the shortest perceived distance overall for their journey. For example, walking on a heavily trafficked road or on a steep incline is perceived as a

4: uMove considers alternative routes that people might choose to take, based on their preferences for environments with higher walking quality

5: The demand proxies are intended as approximations when other source data is not available



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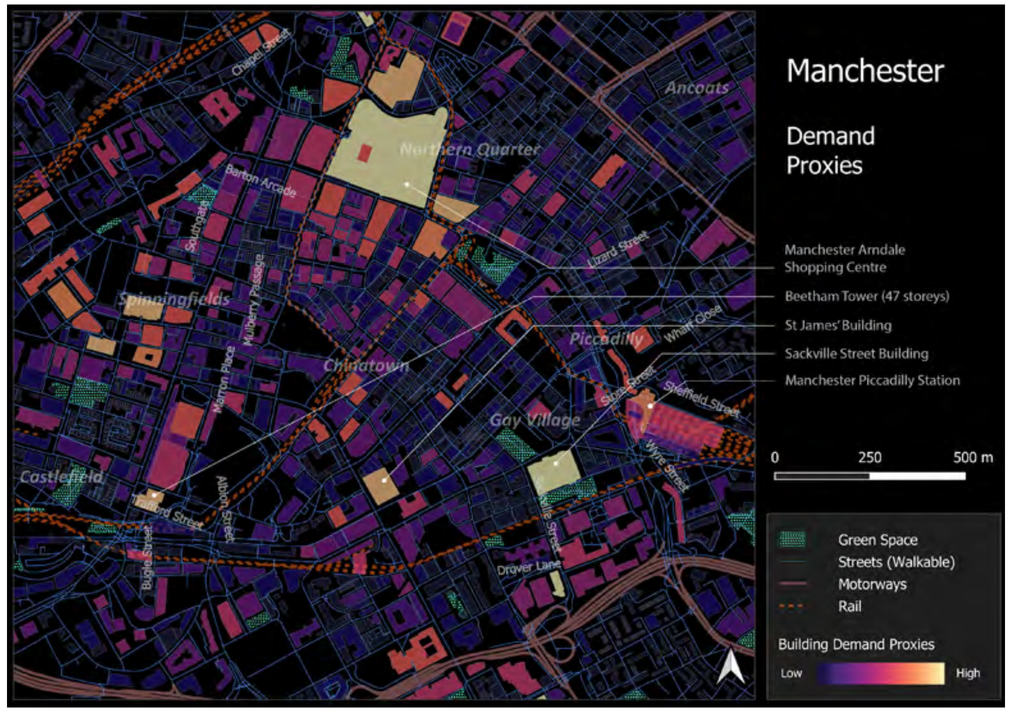

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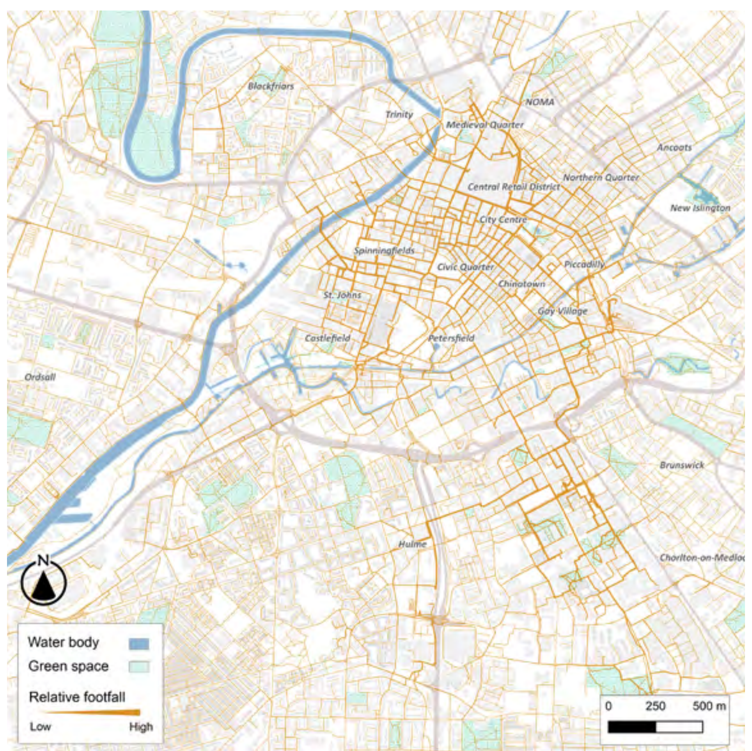
longer walk compared with the same distance covered while walking across a pleasant town square.

The tool creates a measure for walking quality along each link in a network, using indicators drawn from open data, and is further informed by different quantitative findings from prior empirical research.

One of the standout features of uMove is its efficiency. Traditional methods of street analysis involve time-consuming surveys, data collection and manual assessments. Instead, uMove streamlines a set of automated processes that simultaneously builds up a network and calculates numerous performance metrics, helping its end-users to inform intervention measures across large areas. This efficient approach significantly reduces the time required for data collection and analysis. In this way, it allows urban planners and designers to make informed decisions in a matter of days rather than months.

Questions uMove can provide insights into

- Which routes are desirable?
- What if we add a particular transport link?
- What if we connect blocks? What if we disconnect blocks?
- What if we add more retail options?



7.

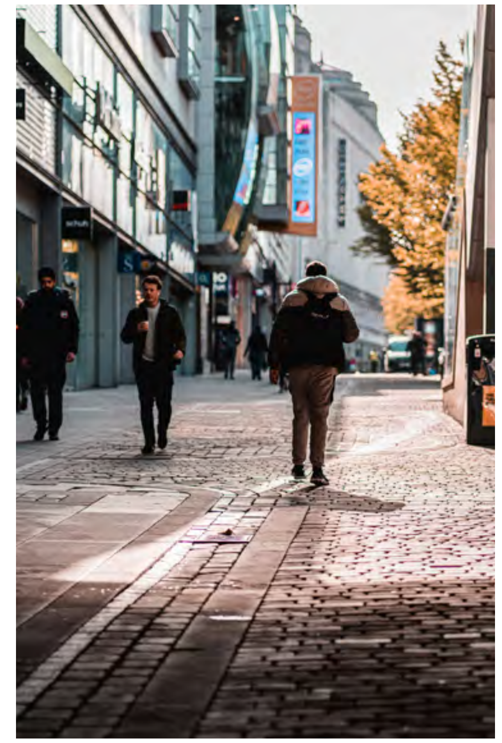
6: uMove calculates demand proxies based on details in OSM data

7: It also generates relative footfall scores, representing how busy one route might be in comparison with another

Understanding and predicting pedestrian travel patterns in urban areas

uMove can be used to generate relative footfall scores, representing how busy one route might be in comparison with another. This can be performed in the absence of pedestrian counts or survey data, and is another feature of the tool that makes it powerful for analysing expansive areas and lending high-level insight when no other data sources are available. However, the relative footfall analysis should not be confused with actual volumes, as this is not possible using network data from open sources alone. Instead, the measure provides a data-driven 'relative busyness' score. When third party counts do exist for certain roads or intersections, it is possible to incorporate them for further calibration of uMove's relative footfall scoring approach.

The tool calculates demand proxies based on several details in OSM data. Factors considered include building footprint (area); height (number of storeys); type (dwelling density, i.e. people/area); and activity rates (amount of turnover per day). The demand proxies are intended as approximations when other sources – such as spot counts, surveys, and camera/AI or mobile phone data – are not available.



8.

8: uMove enabled Arup's designers to spend more time focusing on developing contextually responsive streetscape interventions

9: The Council's aim is to reduce vehicle journeys in the city centre to deliver air and noise quality improvements

10: Providing places to sit enhances the pedestrian experience

9.

In Manchester, working with the client and stakeholder engagement groups, Arup was able to validate the outputs of uMove to confirm that the identified priority locations within the city centre reflected the local experience of the pedestrian network.

Measures to improve walking and wheeling

After using uMove to review hundreds of kilometres of streets in Manchester city centre and develop a list of priority locations, Arup's designers then focused on identifying contextually responsive interventions to deliver improvements for people walking and wheeling in places with the greatest potential benefits.

Key design interventions the team identified included:

- **Increasing footway widths and improving surface quality:** Inadequate footway widths, clutter and poor surface quality directly impact the accessibility and experience of people walking and wheeling. Reallocating road space to pedestrians while providing for necessary vehicle, cycle and public transport movement was fundamental to identifying improvements on high-demand city streets.
- **Increasing and improving crossings:** Pedestrian crossings are critical to safe and inclusive walking and wheeling environments. Identifying new and better-located crossing points was essential to the project. Existing crossings were also assessed to understand where wait times were inconvenient and where crossing times were too short for those with mobility impairments.
- **Introducing continuous footways:** Continuous footways give design priority at side road junctions to people walking and wheeling by continuing the footway surfacing and removing level differences. These interventions make it easier

uMove use case examples

- Street type classification: what are the street types in this area?
- Route quality: which roads are pedestrian-friendly?
- Isochrones: how far can I walk in 5, 10, 15 or 20 minutes?
- Demand proxies: where is demand generated?
- Footfall estimates: where is pedestrian activity highest?
- Demand assignment: how are people travelling to this location?

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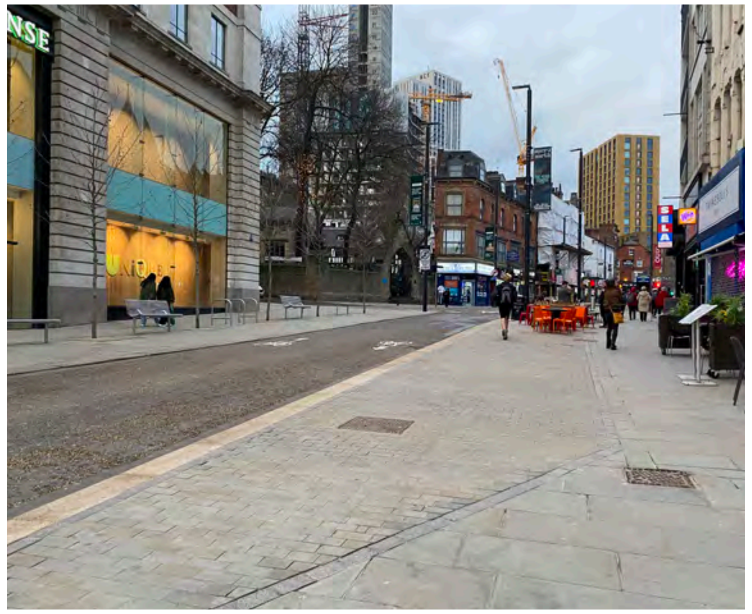

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for all pedestrians to move around while creating a safer environment by prompting drivers to slow down and give way.

- **On-street parking:** Manchester's vision for the city centre includes lower levels of vehicle traffic with reduced on-street parking. The Arup team identified opportunities to remove on-street parking while retaining disabled parking and loading bays. This provided the opportunity for widening footways and adding new seating and green infrastructure. Furthermore, all retained parking bays are proposed to be raised to footway level, meaning that when the bay is not in use, it can function as part of the footway or have other uses, such as a location for seating for hospitality businesses.

- **Making walking and wheeling joyful:** Improving the pedestrian environment is not only about getting the basics right in terms of functionality, but also about making walking and wheeling an attractive and enjoyable experience. Providing places for people to sit and spend time, integrating green infrastructure and making design relevant to the local context can make the pedestrian experience joyful as well as practical. Arup's analysis highlighted a general lack of seating, so the team identified opportunities for seating locations that would not negatively impact on pedestrian movement.

- **Buses:** Buses are essential in making cities more accessible, and naturally combine with walking and wheeling as part of multimodal journeys. However, the location and design of bus stops impacts on the walking and wheeling environment. Consideration of bus stops was a key part of the project, including moving bus stops and changing their design where they narrow the footway width to below desired minimum widths.

- **Drainage:** Poor drainage and associated standing water can adversely affect pedestrians. These issues are often located at changes in levels, such as dropped kerbs at pedestrian crossing points. The study highlighted sustainable urban drainage as a key opportunity across streets in the city centre.

13.

11: Raising loading bays to footway level enables them to function as part of the footway

12: Arup identified opportunities for seating locations where they don't hinder pedestrian movement

13: Consideration of bus stop locations was a key part of the project

14: Interventions such as integrating green infrastructure can help improve drainage as well as enhance the pedestrian experience

14

Focused street design

The uMove tool enables the planning of more pedestrian-friendly spaces by identifying areas with high foot traffic, enabling designers to focus their efforts on high-impact locations. As a result, Manchester City Council now has a pipeline of schemes that will enable it to provide residents and visitors with safer, more inclusive and more pleasant streets for walking and wheeling, improving the overall quality of life in the city.

Enabling more people to walk and wheel for more journeys will support the Council's ambition to reduce vehicle journeys in the city centre, delivering air and noise quality improvements while making the city centre a safer environment for people to move around. Pedestrian infrastructure improvements benefit everyone, but can be transformational in making places more accessible for children, older people and those with mobility impairments. This helps ensure that the city centre is a more equitable and inclusive place.

By using uMove to analyse hundreds of streets quickly and accurately, Arup has set a new standard for urban development – one that focuses on creating vibrant, pedestrian-friendly city centres that benefit everyone. As other cities look to improve their own urban landscapes, uMove serves as a prime example of how technology can be harnessed to create more livable, efficient and sustainable urban environments. Arup is currently developing a cycling component of uMove to take account of how cyclists may prefer longer routes that have better cycling provision, lower traffic levels or avoid steep inclines.

Authors

Rachel Cornfoot was the Project Manager. She is a senior transport planner in the Manchester office.

Adrien Friesen is the uMove product manager and a senior digital consultant in the London office.

Peter Webster was the Project Director. He is an Associate Director in the Manchester office.

Project credits

Client Manchester City Council

Data analysis, digital design, masterplanning, scripting, transport consulting, urban design, visualisation Arup: Rachel Cornfoot, Adrien Friesen, Brett Little, Stephen Murtagh, John Townsend, Peter Webster.

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15: A focus on improving walking and wheeling routes will encourage people to use active travel on a daily basis

15.

Raising the bar

The challenges of designing a new university campus that spans above a subway station

Authors Hironori Hisaki, Junichiro Ito, Mitsuhiro Kanada

Nagoya Zokei University is a renowned art and design university in Japan's fourth most populous city. When it chose to move its entire campus from the outskirts of the city into the bustling urban centre, severe physical limitations on the new site and potential exposure to earthquakes were the catalysts for a highly innovative and inventive building design.

Arup provided structural engineering, seismic design, and mechanical, electrical and plumbing (MEP) services for the 20,917m^2 project, which has a subway station and line running below the site. To avoid putting additional load on the upper part of the station, the decision was made to elevate the building using a bridge-like design straddling the subway, with a 40m-wide steel truss spanning between concrete cores. The design creates a central 'art street' that passes through the building, offering a semi-outdoor space to the local community which encourages social interaction through art. The truss supports a massive flexible studio on the fourth floor that features only a few standing walls and just one type of thin diagonal bracing.

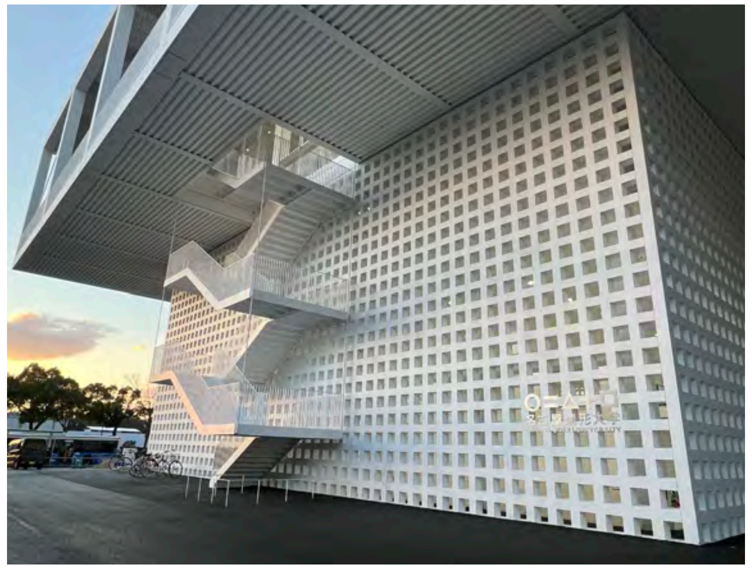
Aichi Prefecture, where the university is situated, is in an active earthquake zone where solid seismic walls are a necessity. To ensure the seismic performance, Arup adopted highly transparent, earthquake-resistant, precast hybrid concrete and steel lattice walls to connect the foundation and the fourth floor. The walls wrap around the university, combining elegant architectural design with precise

1.

1: A key design feature of the new Nagoya Zokei University is a central 'art street' that passes through the building


2.

2: The structure features transparent, earthquake-resistant, precast hybrid concrete and steel lattice walls that connect the foundation and the fourth floor

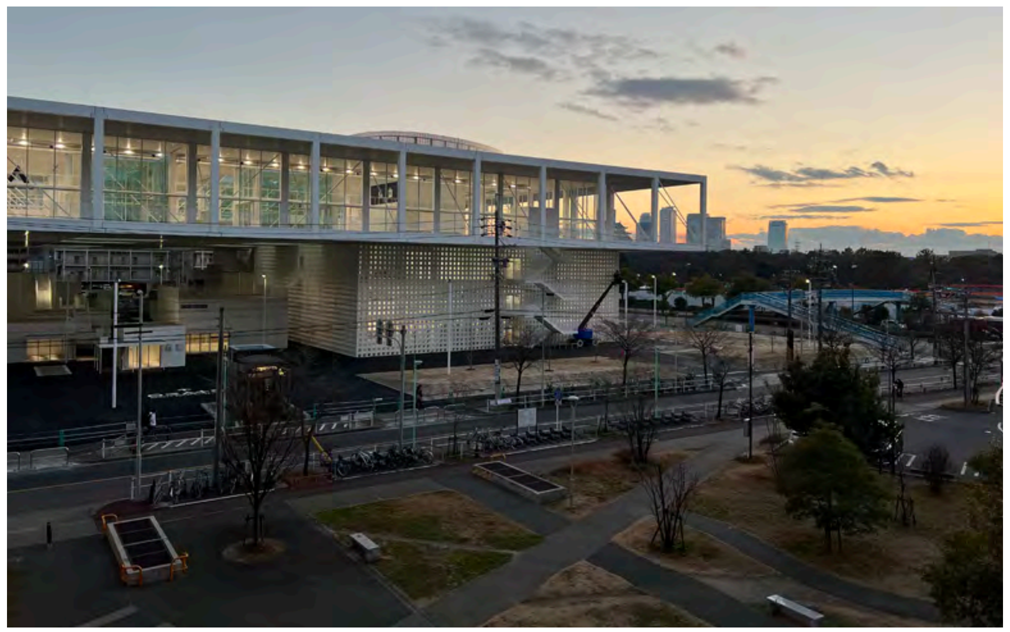


3.

3: The innovative use of lattice walls minimises material use and increases seismic resilience

4: Nagoya Zokei University is a renowned art and design university in Japan's fourth most populous city

5 & 6: The fourth floor includes an external terrace which can be used as an open studio



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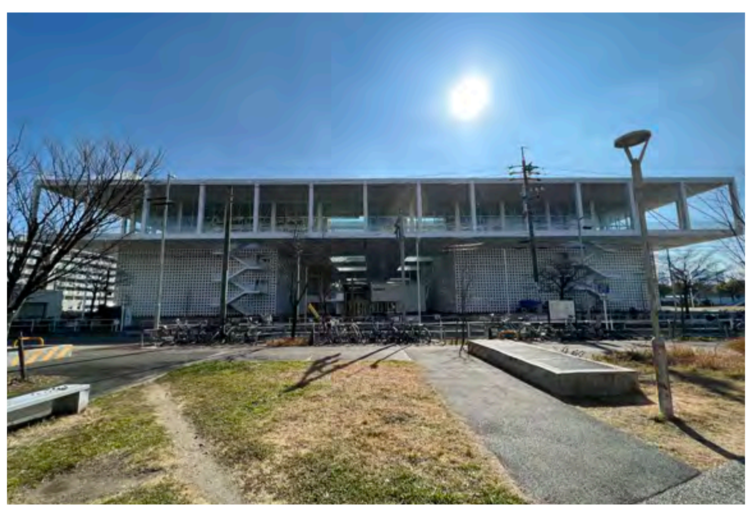

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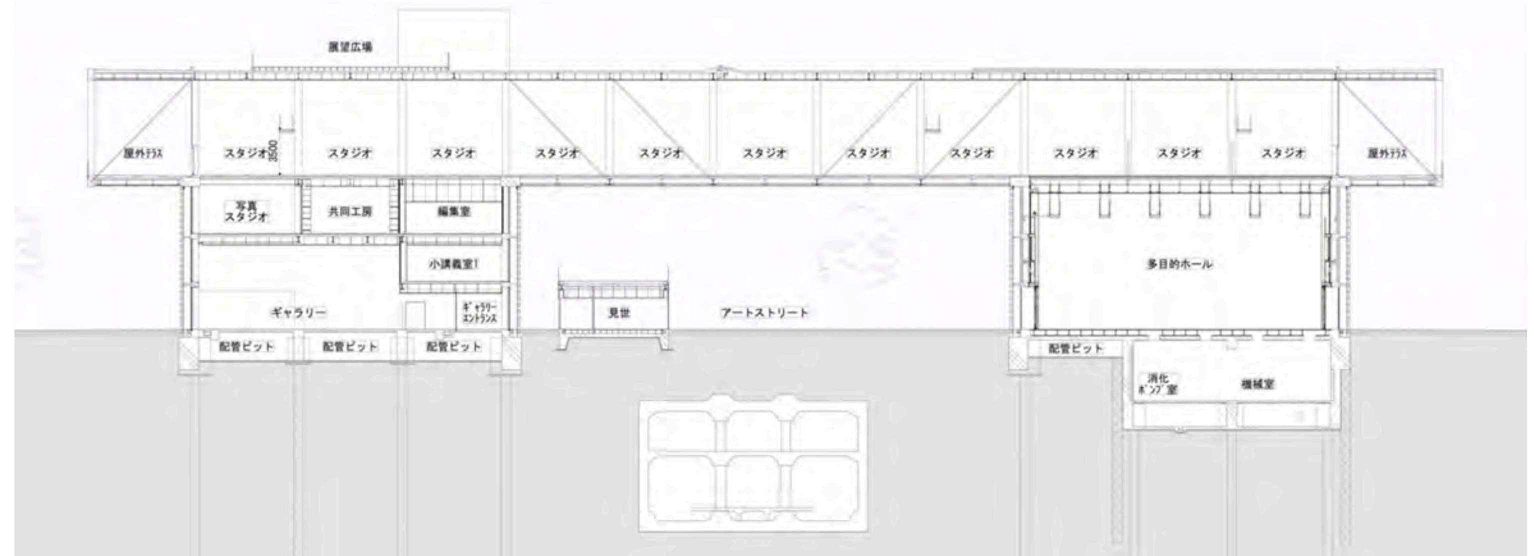
seismic engineering at very fine scale. This structural scheme using lattice walls is an innovative strategy that minimises material use and improves the bearing capacity, leading to increased seismic resilience. All of the structure is exposed and integrated with the architectural design. This eliminates short lifespan finishes and contributes to the whole-life sustainability of the project.

Furthermore, a focus on low-carbon design inspired the development of a floor cooling and heating radiation system for the studio, lowering overall energy consumption and improving indoor thermal comfort. A sophisticated building energy management system gives the building's facilities management team granular control over systems in different areas and rooms and provides live monitoring data on energy consumption to help optimise performance.

The architectural vision

The plan to relocate the university from a relatively remote location on the outskirts to the city centre began to take shape in 2018. The 4.5-acre site is conveniently located on the eastern side of Meijo Koen Park, a major public park, and close to one of Japan's landmark castles, Nagoya Castle, built in 1612. An existing university laboratory building is located to the south and a development of small houses to the east.

The new building has four 3-storey high concrete blocks (containing a library, lecture halls, a cafeteria, a gym, a gallery and workshop facilities) positioned at each corner, and a basement. The 104m x 104m studio on the fourth floor houses open-plan facilities for students and staff, and an external terrace (which can be used as an open studio).



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Architect Riken Yamamoto is known for projects that physically connect people with their surroundings. Interior spaces often allow users to engage with the outside world, either visually or audibly, and key building functions are pushed to the edges to create space for circulation to draw people in. His 1977 project Yamakawa Villa encapsulated this philosophy, its internal veranda connecting functional spaces on the periphery of the house arranged as a cluster of architectural masses containing bedrooms, bathrooms and a living area.

The same architectural language infuses the design for Nagoya Zokei University, most notably in the semi-open-air art street at ground level. This is accessible by local residents and subway users and incorporates a series of smaller, house-like structures used variously as study areas, exhibition spaces and shops.

Meijo Koen station on the Nagoya Municipal Subway bisects the site from north to south, and stringent safety protocols limited the load-bearing capacity of the station structure to just 10 kN/m^2, making only 1- or 2-storey structures viable. This informed the decision to split the building into two halves, creating the full-length art street above the station, with the truss structure spanning the 40m gap between the four reinforced concrete cores. The truss acts as a roof for the street and releases the open-plan studio space on the fourth floor. The open-plan design was conceived to enhance spaces for art creation and exhibitions, minimising the number of enclosed lecture halls.

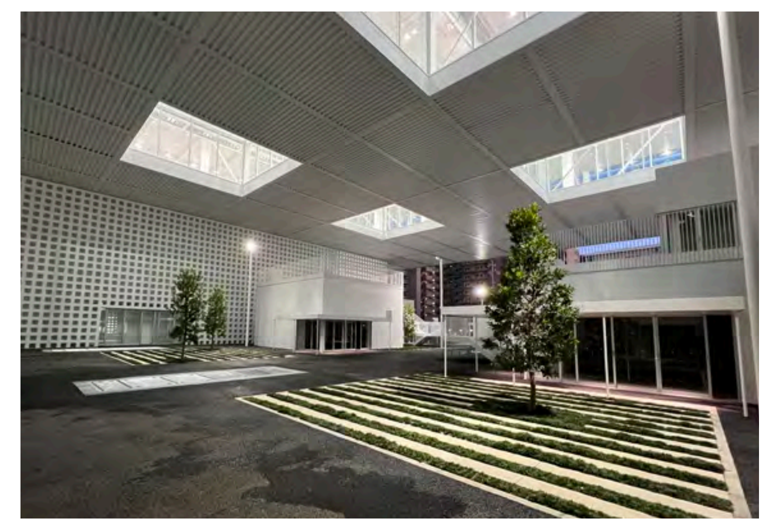
Lattice façade

The architectural ambition to create visual connections between interior and exterior spaces included the design of the perforated ventilated façade enclosing the four cores. Rather than install the lattice as a secondary, non-structural façade element, Arup designed for it to function as a primary, earthquake-resistant structural façade. This is a first for Japan, where seismic walls are typically made of solid reinforced concrete to resist high seismic loads. The lattice façade also reduces the amount of direct sunlight in the interior and allows for natural ventilation, alleviating the load of the building's cooling system and improving environmental performance.

The Arup team initially felt that the lattice elements would be difficult

7: To avoid loading the upper part of the subway station below, a bridge-like design using a 40m-wide steel truss spans between concrete cores

8: This design creates the central 'art street', offering a semi-outdoor space to the local community which encourages social interaction through art



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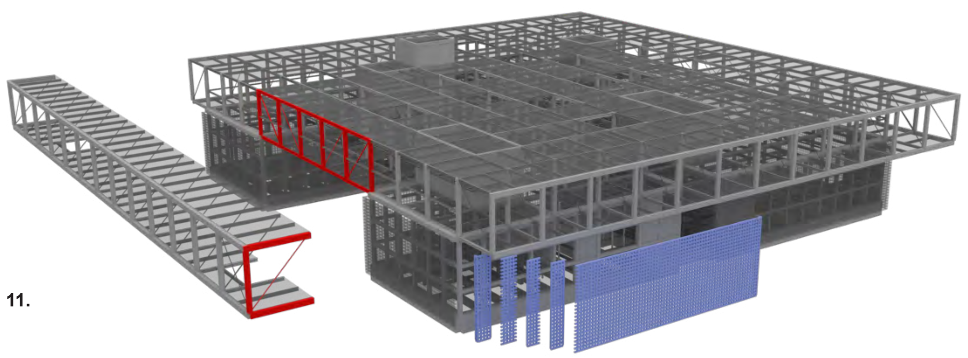
to realise structurally, as the precast lattice devised for Fussa City Hall, a previous project by the same architect, featured larger cross-sectional sizes more appropriate for structural materials. However, through an extensive 18-month design process, Arup developed a workable solution.

The firm developed the lattice into a hybrid steel/concrete outframe that connects the piled foundations to the base of the long-span truss. Set out on a 500mm grid, the 200mm x 200mm precast columns and beams, with 16-22mm steel plates attached to the rear, work in combination with the building's reinforced concrete frame. The lattice does not support vertical forces but resists horizontal forces and maintains uniform rigidity, while the frame ensures overall strength.



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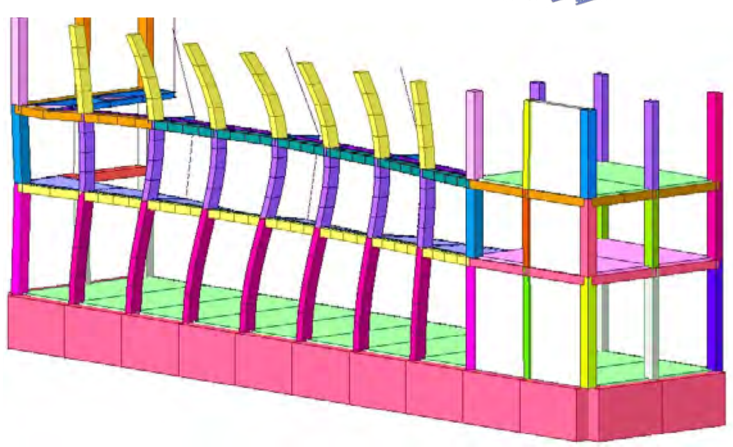

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9: The hybrid steel/concrete outframe is set out on a 500mm grid

10: The outframe features 200mm x 200mm precast columns and beams

11 & 12: Digital tools including LS-DYNA and Midas iGen were used to create and analyse the lattice wall model

The first-of-its-kind design required intensive analysis to verify rigidity, strength and the potential for concrete cracking. The lattice also needed sufficient axial force to prevent the steel plates from buckling. An international effort saw structural engineering teams in Arup's Japan and London offices collaborate, using digital tools including LS-DYNA and Midas iGen to create and analyse the lattice wall model.

Efforts to refine the design ultimately paid off; real-life stress tests by Obayashi Technical Research Institute confirmed that the precast panels sufficiently stiffened and prevented buckling in the steel plate, and design strength and stiffness verified the calculations.

Seismic loads are not the only forces the lattice walls have to resist; they must also absorb horizontal forces generated by the truss above. Special joints and bolts were developed to transmit the large shear forces from the truss into the columns, but not the axial forces generated by the downward weight of the truss.

Bolts and joints on the column heads posed a problem for the structural design. Repeated earthquakes form gaps between round bolts and holes that would prevent seismic forces from being properly transmitted into the lattice wall. To overcome this issue, specially machined square bolts were developed to connect into custom bearing plates on the column heads. This arrangement improves the bearing surface, boosts overall shear strength and, in an earthquake, allows the lattice walls to shift and then return to their original position.

13.

13: Strain gauges were attached to the steel plates and demonstrated that stresses caused by concrete shrinkage would not affect the bearing capacity

14: Testing in the Obayashi Technical Research Institute confirmed the design strength and stiffness of the precast panels

15. A total of 300 factory-made lattice wall panels were fixed together on site

Fabrication of the lattice wall panels raised further issues due to concerns that shrinkage as the concrete dried would put stress on the steel plates, causing tolerance issues. Analysis revealed that tolerance could be reduced to within 5mm by adopting low drying shrinkage concrete and installing special supports after the steel plates were formed. Strain gauges were subsequently attached to the steel plates and demonstrated that stresses caused by concrete shrinkage would not affect the bearing capacity.

Moving into construction, the precast lattice panels were welded together at various points, including along the steel plates and connecting reinforcement bars. Very little expansion or contraction in the panels was predicted once the reinforced concrete frame was completed, yet there were concerns about whether the welding might shrink the walls and cause cracks in the concrete.

Some 0.1mm cracks did appear on the surface of panels when work began on welding the reinforcement. Collaborating with the contractor, welding jigs were used to apply compressive force to the rebar in advance of welding, which proved successful in overcoming this issue. In all, a total of 300 factory-made lattice wall panels were fixed together on site using approximately 6,300 joints.

Reinforced concrete frame

The design team refined the size and weight of the structure further through the reinforced concrete frame. The designed columns have a thin cross-section, of just 400mm x 600mm, which prohibits any form of bending if the structural design is to function effectively.

Large-span reinforced concrete beams with steel pin joints at the ends were developed to transmit shear forces in the structure. The pin-jointed beams helped minimise bending moments, allowing the columns to support the massive axial forces of the truss more efficiently. Finite element method (FEM) analysis verified the performance of the joints, but difficulties were experienced in production because the steel end plates, into which headed stud bolts are attached, warped under the heat of welding. The plates have to withstand complex stresses in situ, so the patience and diligence of the steel fabricators was key to refining the approach and getting it right.

Flexible spaces

The building design included a new curricular system and academic structure for the university's faculties. The old system of a single art and

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design department with nine different disciplines was transmuted into five separate 'domains' – Art Expression, Visual Literature, Community Area Design, Design of Community Sense, and Representation – each one defined by the architectural configuration.

Learning spaces and studios are spread across the fourth floor, where flexible layouts allow functions to be shifted around to accommodate different teaching styles and learning methodologies. A common area in the centre of the floorplate, known as the Art Plaza, is where students and professors meet to discuss and exchange ideas, and where people from different studios and domains can see what is going on in other studios.

The need for flexibility and seamless spaces, coupled with the drive towards architectural elegance, saw Arup work to minimise the cross-layer truss structure as much as possible and virtually eliminate the need for diagonal bracing and standing walls – a particularly tough target for a building in an active earthquake zone. Developing a constructable solution was a complex process, as several different constraints had to be factored into the final truss design. The approach, at concept stage, was to create a fully precast concrete building, partly because of the architectural preference for the texture and appearance of concrete over steel. The structure included only an intermediate storey truss over the internal street.

The scheme evolved, during detailed design, into an inter-storey precast concrete truss. However, this structure was found to be prohibitively heavy, required thick diagonal bracing, and involved substantial costs related to heavy machinery on site. Instead, Arup proposed a full inter-storey steel truss constructed on top of a 3-storey high reinforced concrete frame. This design reduced costs, required only one type of slender diagonal bracing element spanning the studio space, and reduced the size of cranes needed for installation.

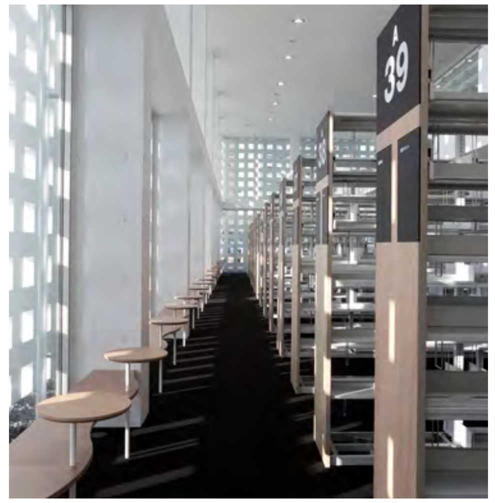
Steel truss

Switching to a steel frame for the truss still posed challenges, though. There were concerns over potential floor vibration in the studios caused by trains travelling through the subway station below. Thick steel bracing sections are normally used in Japan to resist earthquakes, prevent deformation and reduce vibration. The Arup team calculated that, by using a reinforced concrete floor slab for the fourth floor, the extra mass would dampen vibration and make it possible to reduce the cross-sectional size of the inter-storey truss diagonals. Nevertheless, the slender 11m-long diagonals were still predicted to experience considerable deformation, potentially by as much as 100mm.

Arup therefore turned to the onsite welding process to minimise deformation by increasing the amount of tension in the bracing. The steel portal frame for the truss was erected first, then the diagonal bracing was installed and welded at each end to fixed joints. The 7.25mm gap between the portal frame and the bracing naturally contracts by 1-2mm when welding is carried out, creating tension in the diagonals and compression in the framing, and resulting in a much stiffer structure to withstand loads.

This novel approach required detailed examination and testing before it could be implemented on site. The construction sequence was reviewed by a structural engineering team in Arup's Hong Kong office and a full-scale mock-up of a truss joint was built. The welding itself was highly challenging due to the thickness of the members, the difficult angles of joint connections and the behaviour of welding wire under heat.

Ultimately, by using a combination of two different weld positions, changing the type of welding wire according to weld difficulty, and altering the temperature of the weld area between passes, it was possible to maintain workability, achieve the necessary tensile strength and pass the Charpy impact test (a standardised high strain rate test which determines the amount of energy a material absorbs during fracture). The expertise of Japanese construction company Tomoe Corporation was critical to achieving this result.



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16: All of the structure is exposed and integrated with the architectural design

17: The lattice façade reduces the amount of direct sunlight in the interior and allows for natural ventilation

18: The lattice design is a first for Japan, where seismic walls are typically made of solid reinforced concrete to resist high seismic loads

Energy management

Efforts to manage temperatures of a very different kind came into play when Arup was developing the scheme for the building's MEP systems. The open-plan 6,000m^2 studio features a large, 2-storey atrium, and relying only on a conventional air flow HVAC system to maintain thermal comfort was considered inefficient. The Arup team opted instead to combine it with an underfloor radiation cooling and heating system, cast with the concrete slab, which controls floor surface and room temperature, lowering overall energy consumption and improving indoor thermal comfort.

Furthermore, the limited number of walls on the fourth floor made it necessary to also install power outlets and local area networks within the floor. An innovative 'MEP-Trough' cable route was installed in the slab before radiation pipe installation and concrete casting to prevent electrical cables and floor radiation pipes interfering with each other. This trough also contributes to preventing concrete cracking due to thermal expansion.

In another bid to drive down operational energy usage, as well as enable more effective facilities management, Arup devised a new process for building energy management and equipment monitoring. The cutting-edge building energy management system can operate electrical systems separately in different floors and areas of the building, including separate rooms in each department. It can also individually monitor the performance of equipment such as lighting, HVAC, ventilation, hot water and power outlets. This is predicted to reduce the building's overall energy use by 10%.

New connections

In successfully providing structural and MEP services for Nagoya Zokei University, Arup has played a key role in delivering an iconic, resilient and sustainable building that is a prominent new base for education and cultural development in central Japan.

The transparent and open design is already helping forge new connections between students and the local community. The public access to the library, cafeteria, shops and the art street all help to root the university within its vibrant new urban context.

Authors

Hironori Hisaki worked on the building services design. He is a mechanical and electrical engineer in the Tokyo office.

Junichiro Ito was the Project Manager of the structural team. He is an Associate in the Tokyo office.

Mitsuhiro Kanada was the Project Director. He is a Director in the Tokyo office.

Project credits

Client Doho Gakuen
Architect Riken Yamamoto
Main contractor OBAYASHI CORPORATION
Steel frame contractor Tomoe Corporation
Facilities management, mechanical and electrical engineering, seismic design, structural engineer Arup: Kazuma Goto, Hironori Hisaki, Genki Ikeda, Junichiro Ito, Shintaro Ito, Mitsuhiro Kanada, Masahiro Kawabata, Seolmi Kim, Shintaro Kobayashi, Hirotaka Ogihara, Tsubasa Takeuchi.

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1, 3-16: Arup
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17, 18: Shigeru Ohno

18.

Gas field facility removed from head to toe

Decommissioning Ireland's first indigenous gas fields

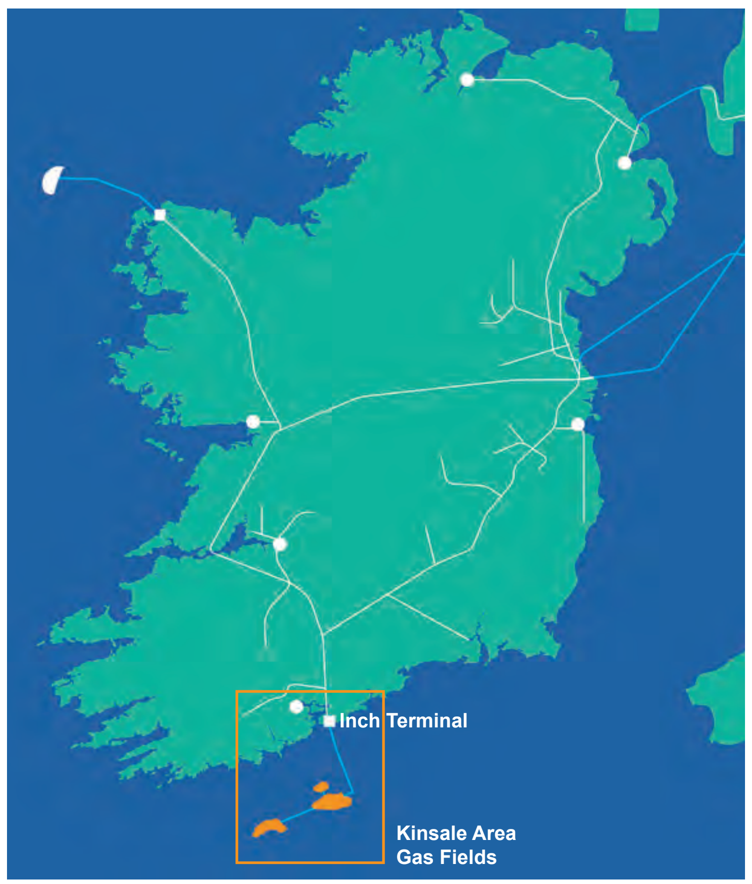
Authors Paul Brady, Sheila O'Sullivan

Located in the Celtic Sea, the Kinsale Area Gas Fields were Ireland's first indigenous gas fields. Discovered in 1971 and developed from 1977 to 2003, the fields supplied all of the island's natural gas from 1978 to 1995, when the first gas interconnector between Scotland and Ireland came onstream. The fields remained the only indigenous source of natural gas until 2015. Gas production from the wells ceased in July 2020 when all the reserves were depleted, with the offshore platforms de-staffed in August 2021.

Over the past decade, Arup's energy and environmental specialists worked with the facility owner, PSE Kinsale Energy Limited, a wholly owned subsidiary of the global energy group PETRONAS, to investigate the best approach to decommission the offshore facilities. The firm put together a clear and concise breakdown of the decommissioning process to enable effective, diligent management of this complex programme. During the decommissioning, which was mainly completed in the summer of 2022, approximately 90% of materials (predominantly steel) were recovered from the gas field facilities and recycled or reused, in line with best practice.

Gas infrastructure

The gas fields at Kinsale Head, along with the connected Ballycotton, Seven Heads and Southwest Kinsale fields, were located off the Irish south coast, between 40km and 70km from County Cork. The gas-bearing reservoirs were in layers of porous and permeable sandstone rock, approximately 840m below sea level. The gas consisted mainly of methane and required only the removal of associated water to ensure it met the required quality levels. This gas conditioning was carried out on offshore platforms; the gas was then compressed to raise its pressure for transport to the Kinsale Energy Inch Terminal in east Cork, where it was



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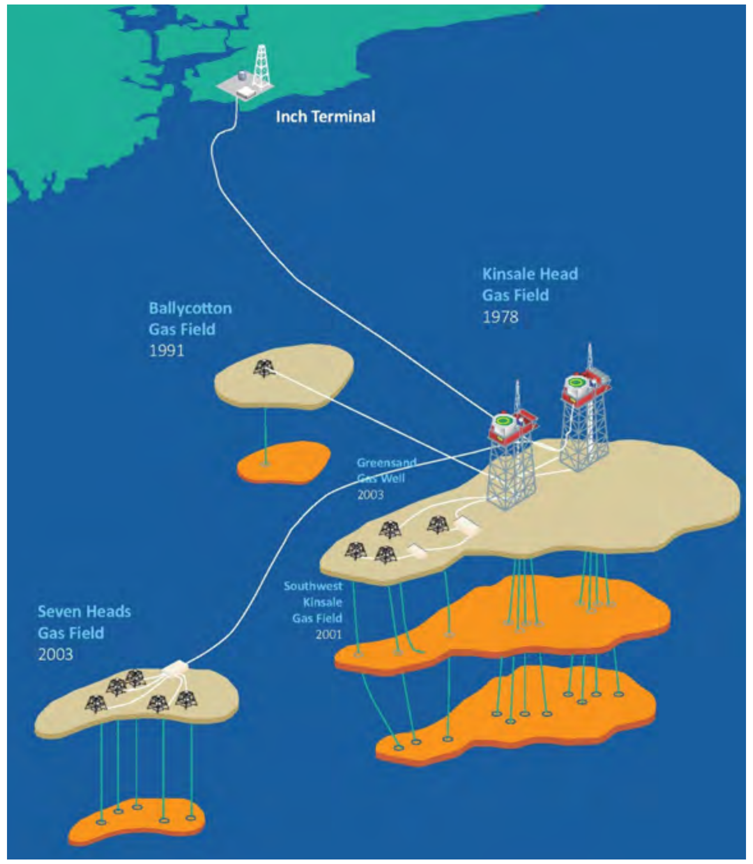
1: The Kinsale Area Gas Fields were located between 40km and 70km off the south coast of Ireland

2: The two offshore platforms were situated in a depth of almost 100m of water



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3: Kinsale Head and three connected gas fields were connected to a network of 153km of subsea pipelines

4 & 5: The Kinsale Alpha and Bravo platforms each weighed approx. 12,000 tonnes

transferred to the national gas grid for domestic heating and power generation.

The offshore infrastructure consisted of two interlinked piled steel platforms, Kinsale Alpha and Kinsale Bravo, located in a depth of close to 100m of water, each weighing around 12,000 tonnes. In addition to the two platforms, the offshore facilities were connected to a network of 153km of subsea pipelines, 28 production wells and an onshore terminal.

Arup was involved from the early 1990s in the design of several structural modifications to the original offshore facilities. These included subsea field developments that required the addition of major cantilever structures: a new 800 tonne compression cantilever and 400 tonne process cantilever; the addition of risers, j-tubes supporting connections from the seabed to the topside of the platforms, and ship fenders on the platform jacket legs; blast wall modifications; crane replacements; and wellhead protection structures. Arup provided topside structural engineering services on all these projects and structural advice on the platform jackets. The firm also fulfilled project management and coordination roles for these works.

Digital modelling

As part of Arup's work on the platforms, the firm carried out an analysis of the complete platforms for a large number of static load permutations, dynamic response characteristics and fatigue loading conditions using Structural Analysis and Design Computer System (SACS) offshore structural analysis and design software. Arup developed a Building Information Modeling (BIM) model converting historical 2D drawings, documentation and the analytical SACS structural model into a complete as-built parametric 3D model using Revit Structure software. The model included linked components, such as product specifications, historical photographs, visual inspection records and reports, bringing over 30 years of operational information together into one digital model.

The firm also developed an inspection regime, along with a bespoke inspection application containing an automated link between the inspection results, asset database and management tool. By modelling the 4,000 elements on each platform, it gave the client a detailed record of their asset.

Alternatives to decommissioning

Before the depletion of the gas reserves, a study was conducted to determine the possibility of reusing the offshore facilities. The high-level options reviewed included hydrocarbon production, offshore transport and storage aspects of carbon dioxide capture and storage from onshore emitters, and offshore wind energy production. However, as findings from this review concluded that none of the alternative uses were feasible, the client proceeded with Arup to plan the decommissioning of the facilities.

While the 'leave in situ' scenario would usually be considered in the alternatives assessment, as per the Environmental Impact Assessment (EIA) Directive, this option was not developed. The reasoning for this was twofold: part of the petroleum leases covering Kinsale Head required the facilities to be decommissioned; and the Convention for the Protection of the Marine Environment of the North-East Atlantic (the OSPAR Convention) prohibited leaving disused offshore installations wholly or partly in place within the OSPAR maritime area, where the facilities were located.

Arup, working with environmental consultants Hartley Anderson, created a new method to carry out a comparative assessment of the subsea pipelines to determine the best way to decommission them. Offshore pipelines are not covered by OSPAR Decision 98/3, which determines the requirements for the disposal of disused offshore installations. Therefore, a comparative assessment was carried out on the subsea pipelines, umbilicals and related protection materials, and the onshore section of the export pipeline.

These studies reviewed a variation on four high-level options which ranged from complete or partial removal, to the leaving of infrastructure in situ, with varying degrees of remediation. The criteria for evaluating the potential impact of the various options were developed for five categories: safety, environment, technical feasibility, society and cost. Out of the possible options, the most favourable was to leave the pipelines and umbilicals in situ with suitable rock protection, while the full removal of the infrastructure was the least favourable across all categories.

Decommissioning planning

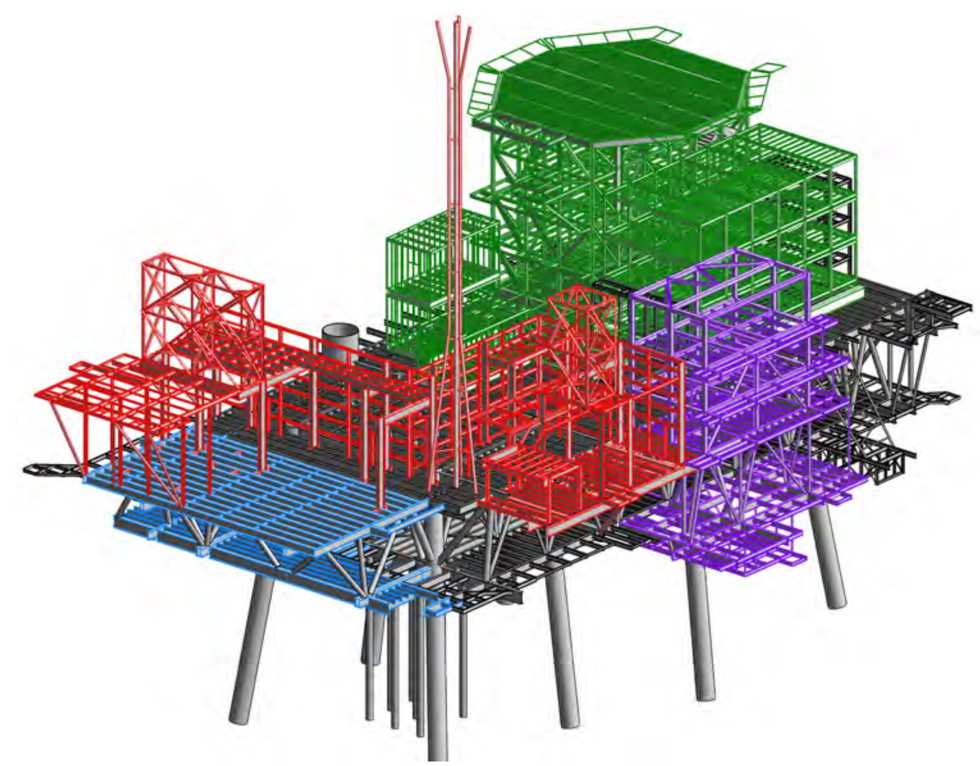
The decommissioning of gas infrastructure is a delicate task, requiring detailed studies such as structural assessments and rigorous EIAs to obtain the necessary consents. Kinsale Head was the first facility to be decommissioned in Ireland, and therefore it was the first time that a facility owner and consenting authority had to apply for and approve such a decommissioning.

Arup carried out initial work that included an early-stage decommissioning options assessment study. This involved preparing an inventory of facilities to be decommissioned, examining the relevant legislation and decommissioning options, and ranking the various options against safety, technical feasibility, environmental, financial and socio-economic criteria. Arup also provided structural engineering assessments of the structures to be decommissioned.

Several decommissioning options were identified through a series of engineering and environmental studies. Any potential impacts that could arise from activities associated with the decommissioning project were identified. A full material take-off was built up from the BIM model to determine the full weight of the structure's components and to analyse how the structure could be safely deconstructed.

The firm's focus then shifted to preparing the required extensive planning and regulatory consent submissions for the decommissioning of the gas fields, and to provide various engineering support to the project, and health and safety advisory services to PSE Kinsale Energy Limited and its contractors. As the project fell within the ambit of European Union (EU) Environmental and Habitats Directives, it was required to follow the relevant assessment processes; these included Comparative Assessments, EIA scoping, Appropriate Assessment Screening, Environmental Impact Statement, and Natura Impact Statement preparation.

Arup managed the detailed stakeholder planning and engagement programme.



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6: Arup used over 30 years of operational information to develop a BIM model of each platform

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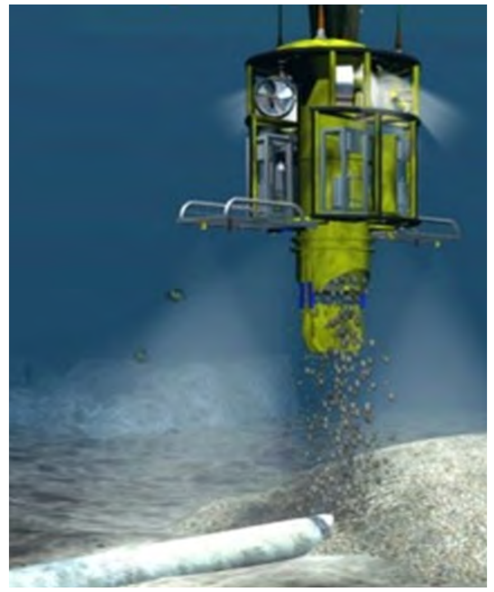

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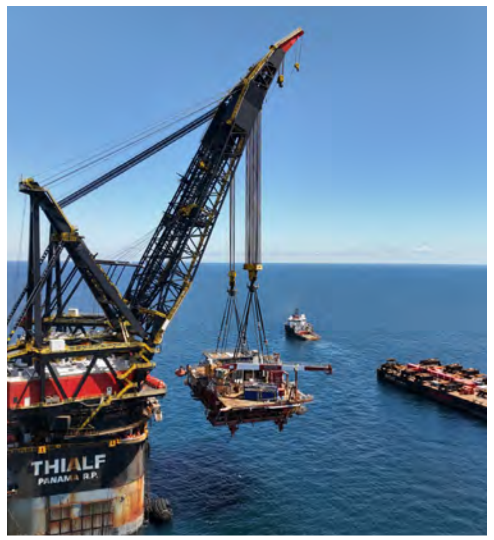
7: The process of decommissioning included removing the platforms down to seabed level

8: Rock protection was placed above the pipelines and cables that were left in situ



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This included consultation with, among others, statutory bodies, government departments, local authorities, utility companies, fishing authorities, public representatives and landowners. Two public consultation information sessions took place – one in Cork city centre and the second in the Aghada Community Centre in east Cork, close to the Inch Terminal. The firm devised a planning process in line with existing legislation and communicated and agreed the process with all parties.

Decommissioning implementation

The decommissioning process involved making the facilities hydrocarbon-free, capping and plugging all wells with cement (14 in total), and removing the platforms down to seabed level. Then came the removal of subsea infrastructure including pipe manifolds, valve assemblies, wellhead structures, and steel and concrete wellhead protection facilities. Specialised marine contractor TechnipFMC completed this work during the summer of 2021, using dive support and construction support vessels.

As determined from the detailed comparative assessment, leaving the pipelines and cables in situ was less disruptive than removal. The specialised rock placement vessel Flintstone installed the rock protection as required, including specially engineered rock berms at the ends of all subsea pipelines. Rock protection was also added to sections of pipeline free span (where the pipeline was not supported directly on the seabed). The onshore pipeline section was left in situ and filled with water; this approach enables the option to reuse this pipeline in the future while minimising impacts. The decommissioning work on the onshore Inch Terminal was completed by May 2022.

The major work to remove the Alpha and Bravo structures was carried out in 2022 by Heerema's floating crane vessel Thialf – one of the largest crane vessels in the world. The Bravo topside was removed in June, using one lift from the supporting jacket structure, and transferred to a transport barge. Subsequently, the jacket was removed by cutting and recovering the upper section and then removing the foundation sections. The entire process, including the Alpha platform removal, was completed by mid-September. Following its removal, the structures were transported to the port of Vlissingen in the Netherlands for disassembly and recycling.

The equipment recovered was safely disposed of at facilities onshore, where it was dismantled and recycled. In line with circular economy principles, all waste was recycled and reused according to waste and environmental management plans developed by the Arup team, with non-recyclable items disposed of in a controlled manner in approved waste facilities.

Following these works, several surveys were carried out on the sites of the decommissioned facilities and pipelines. Sediment samples were also taken to confirm that no contamination had occurred during the decommissioning programme.

In 2023, Arup was appointed as the consultant to manage and administer the post-decommissioning pipeline inspection and monitoring programme on behalf of PSE Kinsale Energy Limited. At regular intervals over a period of ten years, the firm will obtain consent for, procure, manage and supervise offshore geophysical surveys of the area to ensure all pipelines and umbilicals remain stable on the seabed. Following each survey, Arup will prepare reports to share with both PSE Kinsale Energy Limited and the Irish regulator.

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9: The Bravo topside was removed, using one lift from the supporting jacket structure, and transferred to a transport barge

10: The Kinsale Energy Inch Terminal in east Cork was decommissioned as part of the project

11: The major work to remove the Alpha and Bravo structures was carried out by Thialf, one of the largest floating crane vessels in the world

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Project credits

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7, 9: Heerema
11: Kees Torn

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Wastewater – a reflection of our health

The role of wastewater-based epidemiology in monitoring and improving public health

Authors Olivia Bailey, Bhavik Barochia, Tom Doyle, Joe Shuttleworth, Vikki Williams

As the COVID-19 pandemic took hold in 2020, governments across the world were looking to alternative sources of health data to track viral spread more effectively in the population. It was during this time that they discovered the value of wastewater. Through monitoring biomarkers found in sewage, wastewater-based epidemiology (WBE) can provide invaluable insights into public health. Because humans begin secreting biomarkers into sewage days before COVID-19 symptoms develop, WBE can be used as an early warning system to identify viral hotspots before they become visible in clinical data, helping to track the spread of infection across populations.

During the pandemic, Arup delivered a range of WBE work packages for the UK Government, developing innovative digital tools, models and sampling techniques to enable the source-tracing of outbreaks of COVID-19 through wastewater sampling. The firm's work required extensive collaboration with government departments, leading academic institutions and the private sector. The wastewater monitoring programme proved to be a reliable new source of public health data in Wales,

1: Having used wastewater-based epidemiology to track the spread of COVID-19, Arup is now exploring how wastewater monitoring can provide insights into a range of health-related issues

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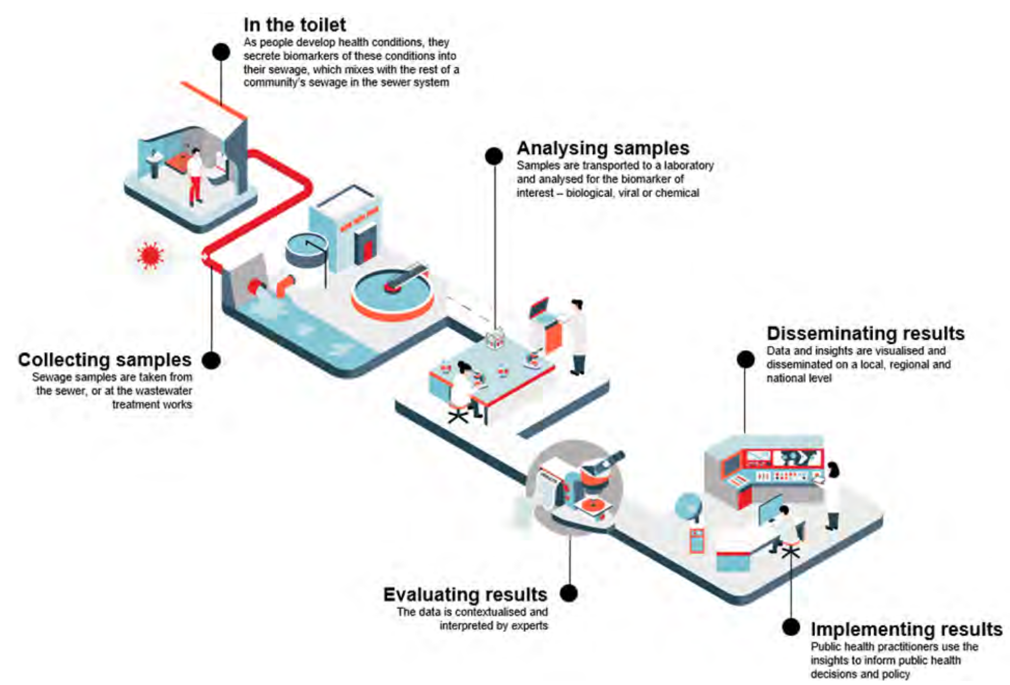
2: During the pandemic, Arup strategised and facilitated the operational delivery of the Welsh national wastewater monitoring programme

3: Sampling and testing took place at 50 wastewater sites across Wales

4: The programme showed how, by monitoring biomarkers found in sewage, WBE can provide invaluable insights into public health

providing daily insights about the health of the nation.

While, thankfully, the World Health Organization declared an end to COVID-19 as a public health emergency in May 2023, WBE is an area of work that is continuing to develop. Beyond infectious disease, wastewater monitoring can also provide insights into a range of health markers, from diet and pharmaceutical consumption to stress hormones and serotonin levels, as well as antimicrobial resistance, environmental pollution and biohazards. Arup is continuing to work with governments, industry and academia to explore how wastewater data can be used in the future to inform health-related responses.



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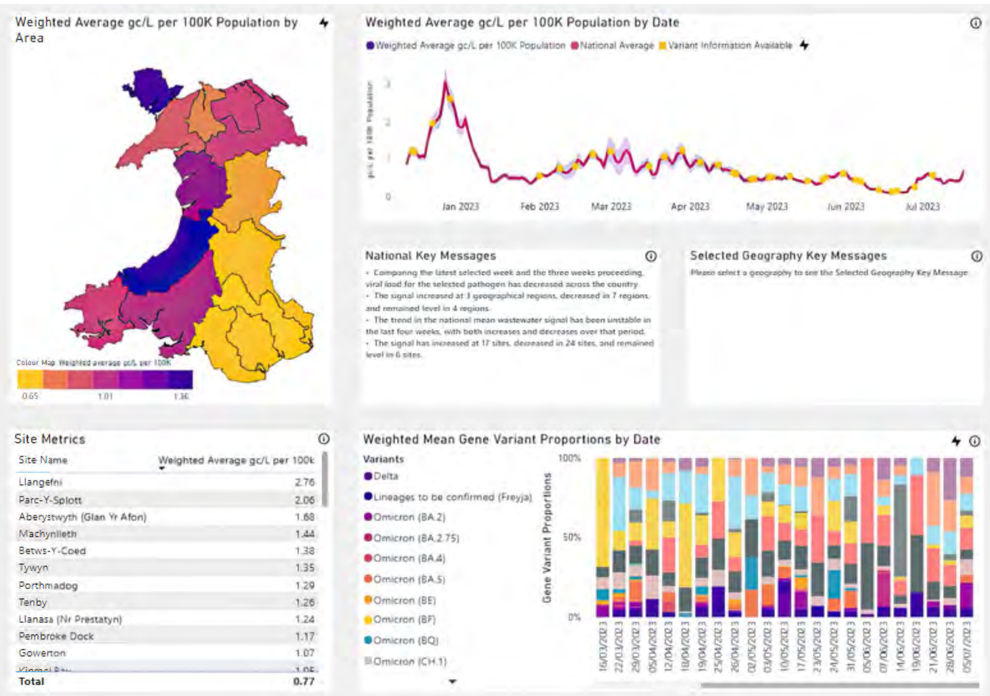
WBE proved an invaluable tool in the fight against COVID-19 in the UK and several other developed nations. However, of the 57 countries worldwide conducting wastewater monitoring, only nine (16%) are from lower-middle or low-income countries. Arup has developed a guidance document to support the implementation of WBE capability in low-resource settings. The aim of the publication is to promote discussions around the value, practicalities and ethics of WBE in various infrastructure settings, and to stimulate public health improvements globally. There is a huge range of health markers that can be used to target health interventions in the areas that need it most.

Wales wastewater programme

Arup strategised and facilitated the operational delivery of the Welsh national wastewater monitoring programme during the pandemic. The project enabled sampling and testing at 50 wastewater sites across the country. The large geographical coverage of testing locations enabled the health monitoring of over 80% of the national population. This was one of the most comprehensive



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programmes globally, and it evolved beyond monitoring COVID-19 to track other infectious diseases, as well as bacterial resistance to antibiotics.

Arup worked in partnership with Bangor University, Cardiff University, the London Data Company, Dŵr Cymru Welsh Water, Severn Trent and Public Health Wales to deliver the monitoring programme. The collaborative approach enabled the sampling, testing and reporting of weekly data on levels of infection within the population – at local, regional and national levels. Testing took place five times a week, delivering real-time information about the levels of a range of different health markers to decision-makers in Public Health Wales and the Welsh Government.

The methods used were more sustainable than previous approaches for disease surveillance in a population. Historical methods of monitoring levels of COVID-19 required manual testing programmes and a large variety of single-use plastics as part of the testing kits. Testing each member of the population was both expensive and inefficient. With the implementation of WBE, a single sample at a large wastewater treatment plant could provide insight into the prevalence of coronavirus for hundreds of thousands of people – providing a rapid, accurate and unbiased method of monitoring for the disease in a cost-efficient and sustainable way.

The work was founded on successful collaboration between government, academia and industry, and brought together deep domain expertise across a number of fields, from hydraulics and water engineering through to virology and public health. Within Arup, the work spanned across geographies and technical disciplines, utilising the firm's expertise on water sampling, knowledge of water infrastructure, and digital design. The project brought together diverse perspectives from different parts of the firm, with input from designers, engineers, data scientists, software developers, microbiologists, programme managers and technical specialists.

The Arup-developed digital tool Fuse was used to coordinate and control the large amounts of project data generated. As a web-based platform, it was made available to the client to help disseminate the data in a secure way, hosted on a hazard insights digital dashboard. This project showcased how public-private partnerships could deliver strong support for national disease surveillance, developing a comparatively low-cost programme in the field of disease monitoring and highlighting the potential for collaboration and innovation in the wastewater sector.

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5: The digital tool Fuse, developed by Arup, was used to coordinate and control the large amounts of data generated by the Welsh programme

6: A single sample at a large wastewater treatment plant was able to provide insight into the prevalence of coronavirus for hundreds of thousands of people

7: The hazard insights digital dashboard was hosted on a secure web-based platform

8: WBE can act as an early warning system for disease outbreaks

9: Its data can be used to monitor the impacts of healthcare practices and predict trends

10: WBE data can be used in conjunction with other datasets to provide evidence for public health planning and decision-making

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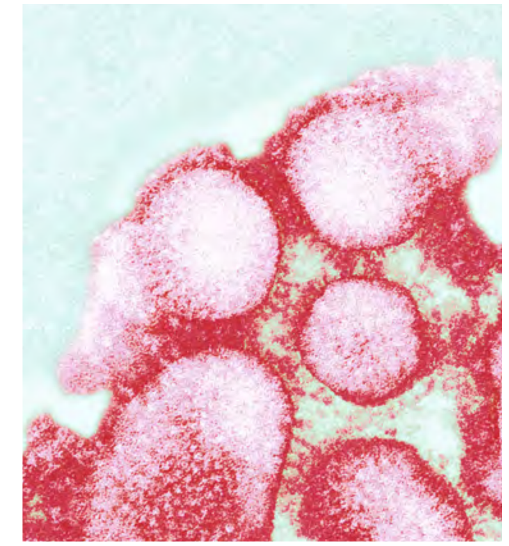

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The future of WBE

The key benefits of WBE are as an early warning system for disease outbreak; to track the spread of an infection across a population; and to identify health trends and inequalities between communities. WBE can be used to inform what services or targeted help might be required in communities by monitoring traces of tobacco, alcohol, and prescription and recreational drugs.

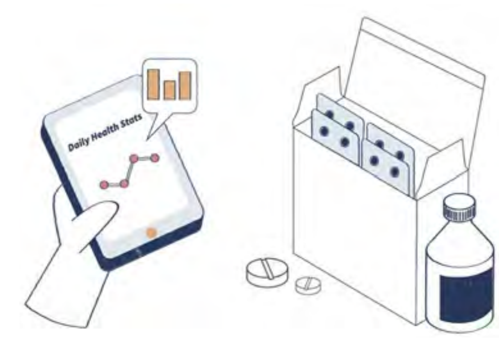
The impact of a WBE programme is dependent on the sampling strategy used, and how the acquired data is analysed to produce suitable information that can inform decision-making. The monitoring gives a fair representation and comparison between communities, and can be used to support preventative health initiatives, targeting resources more effectively by deploying them where they are most needed.

WBE can enable monitoring of large populations to give an honest representation of public health in a city, with data that is anonymised. As the testing and data are aggregated, the monitoring provides an unbiased source of information. It is a holistic snapshot that does not rely on surveys, testing of individuals, or people developing symptoms. This initiative aims to make public health monitoring universally accessible, using wastewater data to develop knowledge of public health and enable evidence-based decisions that could transform healthcare, policy and development activities globally, improve public health, and address health inequalities.

Other public health datasets are often obtained through surveys or focus groups, or at point of use. These offer valuable insights not attainable through WBE, but can miss the wider consequences that can be observed when viewing health data from the population as a whole. WBE offers a dataset that public health practitioners can use alongside current datasets to monitor the impacts of healthcare practices or predict future trends. Ideally, WBE data should be used in conjunction with other available datasets to provide evidence for public health decision-making. For example, comparing wastewater data with case rates, hospitalisation rates and death rates caused by a disease can provide a solid basis for confident intervention. Combined with other data sources, WBE can also help to tell contextual and comparative stories about our health across different geographies and demographics.

WBE can provide us with a snapshot of current health conditions, based on levels of observed markers. Gathering data over time through monitoring can build up an image of how the health of the population is changing, whether to indicate an acute issue or to monitor slow changes over longer time periods.

Testing can also provide a better understanding of a community's physical and mental health by observing factors such as diet (e.g. vitamins, minerals and meat/fish/vegetable consumption), obesity levels and pharmaceutical consumption linked to specific



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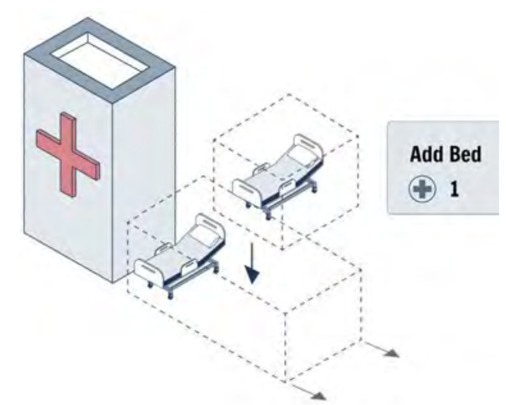

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11: Gathering data over time can start to build up an image of how the health of the population is changing

12: Monitoring biomarkers in sewage can be used to detect disease outbreaks

13: Arup is using lessons learned from WBE in the UK to develop a framework that can be applied in developing countries around the world

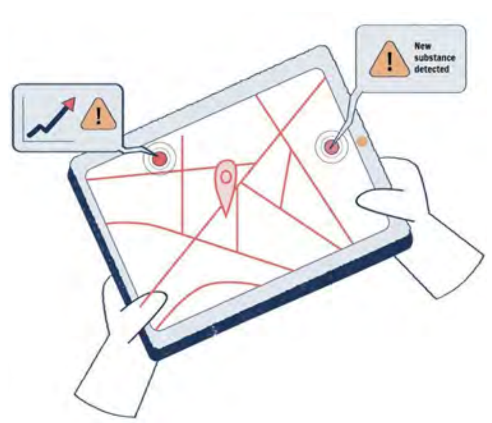
health conditions. Understanding of community mental health status can be achieved through the monitoring of stress hormones, antidepressants and other pharmaceuticals related to mental health.

Improving health in low-income settings

Having experienced the value of WBE in developed sewerage infrastructure, Arup has also explored the potential for using the method to provide health insights for the world's most vulnerable and remote communities. The firm's *Wastewater for Health* report is a guide to support the setup of wastewater monitoring programmes in low-resource settings to improve public health. Arup's research was published open-source, with the aim of promoting discussion and sharing insight into the implementation of WBE globally.

Monitoring biomarkers in sewage can be used to detect disease outbreaks such as norovirus, monkeypox, cholera, influenza, hepatitis, Zika, polio and dengue fever, in addition to coronavirus. This is particularly useful if WBE is implemented in more remote and vulnerable communities where preventative healthcare and resources are less available or not very reliable. In low-income localities, WBE can be used to give an early warning of infectious diseases and flag areas where communities are vulnerable, highlighting where limited resources could be deployed most effectively. Arup's research outlined how a monitoring programme could be set up, how and when to take samples, and what information outcomes could be achieved.

The framework was developed to inform and support the setup of wastewater monitoring programmes in developing markets that have varying degrees of sewerage infrastructure. It can be applied to a range of sanitation systems, from simple single-pit latrines to central wastewater treatment systems. The work was funded by Arup University, the firm's applied research and innovation programme.



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Arup worked extensively with stakeholders to inform and support the setup of wastewater monitoring programmes in developing markets around the world, taking key lessons learned from the pandemic to develop a framework that can be applied to a range of sanitation systems. The firm also worked with the UK Health Security Agency to support the development of insight into the demanding challenges of applying WBE for public health in the science and research space. By combining advanced technology, the firm's expertise in nature-based solutions, and the rapidly evolving urban landscape, Arup has been able to deliver and accelerate adoption on a global scale. By collaborating with international development partners, the firm developed the accessible guide to support others in adopting a similar approach, using wastewater monitoring to protect public health.

The guidance looked at five key areas: infrastructure classification; sampling methodology; degree of testing capability; information outcome; and reflections on non-infrastructure factors. Nine classifications of global wastewater systems were defined as part of the framework. These used the Compendium of Sanitation Systems and Technologies, defined in collaboration between EAWAG (Swiss Federal Institute of Aquatic Science and Technology) and IWA (International Water Association). These classifications range from single-pit systems to sewerage systems with urine diversion.

Key attributes of each technology are highlighted in the framework with the aim of informing suitable WBE technologies. For each system, there is insight into the kind of samples that can be collected and what they represent (physically, demographically and temporally).

Depending on the health marker of interest (whether viral, bacterial or chemical), there are a series of options available to analyse a wastewater sample, varying in complexity. The guidance includes a flowsheet of the processes involved, and reviews commercially available capability. Thereafter, the information outcome segment describes the outcomes and insights into public health that could be achievable through the various sampling and testing scenarios. The guidance's final key area reflects on non-infrastructure factors, specifically local behaviours, cultural barriers, governance and stakeholders.

13.

Scale of monitoring

In the future there could be an opportunity to focus monitoring across household, community and healthcare levels. Monitoring capabilities at the household level could enable new insights into personalised health, and could connect to tailored, preventative health solutions, should users choose to opt in. Community-scale monitoring could enable new insights into the health and wellbeing of an area and inform local urban responses that improve health and address health inequity. Finally, monitoring could enable new insights into demand for health services and inform the short- and long-term planning of healthcare responses.

Authors

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Cardiff University: Amy Baldwin, Isabelle Durance, Peter Kille, William Perry, Andrew Weightman
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