Foreword

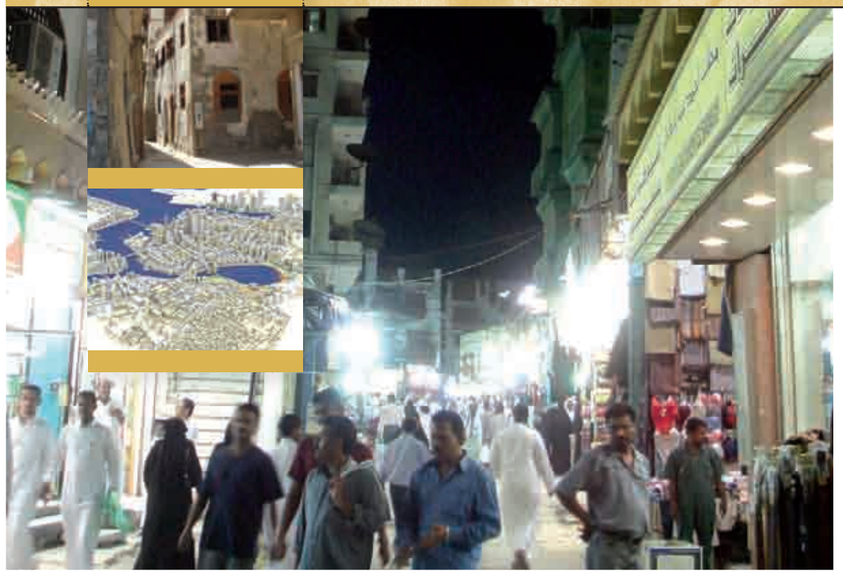
▶ Why do clients come to Arup? They don't come just because we can help them design a new building, plan a new city, or redevelop an infrastructure. They come because of the way in which we do it. They come because we bring elegant simplicity to complex issues. They come because of our unique approach, our focus on solutions – innovative, sustainable solutions that help them keep ahead in a world of transformation.

Our vision of what constitutes design evolves with, and augments, the rapidly changing needs and issues of people across the world. We deliver precedent-setting solutions for today, that make all our tomorrows more possible and exciting. Creativity, innovation and technical excellence, are, in our view inherent to the design process. This book is an illustration of how we approach those things. It is a testament to our clients' aspirations.

We strive to build a working environment where our different values and perspectives are actively harnessed to create the best solutions for our equally diverse client base. We share these ideas, and our skills, around the globe. These solutions are abstracted and developed by professionals all over the firm's worldwide offices. Innovation is pushed into new areas of the industry, new areas of the built environment, new products and new applications in different places. In all this, clients come first, wherever they may be.

This book gives you an insight into the work we have been doing this year. With more than 10,000 Arup projects going on at any one time, the projects you can read about here are just a small selection. Resolving clients' challenges is Arup's mission. We like nothing better than making possible what others think impossible. This book demonstrates Arup's commitment, which we share with our clients everywhere: to shape a better world ■

Project
Jeddah Central District
Location
Jeddah, Kingdom of Saudi Arabia
Client
Urban Development Company



Reconnecting Jeddah with the sea

As the commercial capital of the Kingdom of Saudi Arabia and gateway to the holiest cities in Islam, Jeddah has unique development needs. Its population growth has left its infrastructure struggling, including the sewerage system, whose failure has caused some of Jeddah's lagoons to stagnate, inhibiting development along the waterfront. Arup's strategic masterplan for the central district transforms the waterfront area and provides good public transport infrastructure and well-ventilated thoroughfares. The effect will be to enhance Jeddah's appeal to commercial developers and therefore its land values. The planned higher density development allows public space to increase by a third. The result will be a city that loses none of its historic significance or charm, but gains the best of modern design.

▶ Jeddah defies categorisation. The city known to millions as the starting point for Hajj – the annual pilgrimage in the Muslim calendar to the holy city of Mecca – is a bustling commercial centre, a thriving Saudi holiday resort, and the third largest industrial city in the Kingdom. More than a thousand years of receiving pilgrims bound for Mecca and Islam's second holiest city, Medina, has rubbed off on Jeddah: it is the Kingdom's most cosmopolitan and ethnically-diverse city.

Jeddah's cityscape has been driven by function, influenced by fashion and financed by oil revenue. Early development in the 1930s encircled the historical centre, and the north-south infrastructure is a legacy of the old airport road. The seemingly limitless availability of petrol is reflected in the city's urban road grid, whose sheer scale makes car use inevitable. With no rail or mass transit infrastructure – pilgrims are bussed to the holy sites – it is truly a car owner's town.

Arup was charged with creating a masterplan for the strategic development of a 'protected zone' of five square kilometres between the ancient centre and the waterfront. With a 35% increase in the area of open public space and the potential development for up to 20Mm^2 of mixed-use development, the plan improves the quality of life for Jeddah's citizens, and finances the regeneration of the historic old city centre's heritage. ▶

Cleaning up
The rejuvenation of the city's coastal area is vital for the masterplan's success. A mere 300mm difference between high and low tide means that Jeddah's inner harbours will never be cleansed naturally by tidal movement alone. Rejecting the idea of energy-hungry water pumping, the masterplan team recommended that two dead coral reefs be built up into a water storage basin. Developed by Dutch firm Aveco de Bondt, the basin is a key element of the development strategy. The one-kilometre-square, 15m-deep basin, captures clean seawater at high tide. As the tide ebbs, the water level within the basin falls, and gravity forces seawater down the pipelines into the inner harbour, pushing stagnant water back out to sea. Over 10 years, the harbours will gradually be cleansed by the tides, creating a more attractive – and more valuable – shoreline.

Recovering the waterfront
The development of 12km of coast line for development increases public open space by 35%.

Unlike most cities, Jeddah's waterfront is largely undeveloped: the heavily polluted water has discouraged development. Arup's strategy is to reunite the city with the sea, making a cleaner coastline a top priority. As previously undeveloped waterside land becomes more desirable to developers, the value of real estate in Jeddah will be enhanced.

Key to encouraging thriving commercial development is a series of thoroughfares from the historical centre to the waterfront. Oriented east/west to achieve optimum shading through the day and to provide shelter from the elements, the thoroughfares are lined with carefully designed clusters of high-rise buildings. The topology mimics that of mountains and valleys, with prevailing winds sweeping along the valley floors and promoting ventilation.

These thoroughfares provide easy access for pedestrians and buses alike. The high density of development along them means that, overall, the central district will be more accessible and less reliant on the private car. Public space within the central district will be diverse, featuring mosques, squares, retail, market or gathering places – the better to draw people outside. Like the souk, and traditional buildings in the vernacular style, these public areas will shield people from the sun effectively.

A key element of any sustainable development is a move away from private vehicles, towards public transport. Here the challenges are considerable. While social and environmental aspects of sustainability are broadly accepted by the public, the energy side of sustainability is, for historical reasons, less so. Though there is strong support for the concept of public transport, there are also cultural barriers to overcome.

Public transport users in Jeddah tend to be tourists, pilgrims or low paid workers. Making public transport an alternative to the private car is essential to realising the initial aim that 10% of all journeys in the city should be made by public transport.

Arup's plan tackles such cultural issues by starting small. Women, as well as men, will be able to take public transport in the form of a shuttle bus on short hops along the main transport thoroughfares to destinations such as food markets. They can access efficient, reliable public transport within a few minutes of their homes. If public transport can become an accepted feature of life in the city, it will promote a more sustainable lifestyle for all residents of this ancient, fascinating city

Arup's six key ideas for Jeddah

1 **Recover the waterfront**
- Develop 12km of coastline
- Increase public open space by 35%

2 **Clean coastal water**
- Improve water quality in a 10 year plan

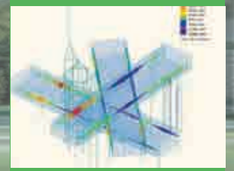
3 **Expand the city centre**
- Finance regeneration through a thriving economic centre

4 **Maximise accessibility**
- Create new infrastructure elements
- Introduce high-quality public transport

5 **Work with the climate**
- Allow prevailing winds into the city
- Orientate urban fabric to minimise energy use

6 **Reunite the city with the sea**
- Create new passages to the waterfront
- Increase shaded area

Project
Centre Pompidou-Metz
Location
Metz, France
Client
Ville de Metz



Raising the roof

Thirty years on from the opening of the Centre Pompidou in Paris, Arup is once again creating an iconic landmark building in France as part of the design team for the Pompidou-Metz. It is conceived as a sister gallery to the Paris landmark – just as bold and spectacular. The challenge is to realise an architectural dream that epitomises a revitalised city and spearheads a large urban regeneration project taking shape on abandoned railway sidings.

main image © CA2M/Shigeru Ban Architects Europe & Jean de Gastines/Artefactory

▶ The city of Metz is located in eastern France, close to the borders of four countries: Germany, Belgium, the Netherlands and Luxembourg. As such the city is at the crossroads of Europe, making it a natural choice for the new Centre Pompidou, designed to decentralise the Paris gallery's vast collection of contemporary art.

The design team, led by Japanese architect Shigeru Ban with Arup, was selected in an architectural competition. As the firm that helped realise the original Centre Pompidou in Paris in the 1970s, Arup is now integral to the design of its regional heir, the Centre Pompidou-Metz. Arup's wide experience of high-profile civic projects and art galleries, as well as its interdisciplinary design approach, provided strong partnership for the cutting-edge architectural team.

The gallery's stunning design combines three contrasting materials that are inter-related and derive support from each other. A steel tower sits at the building's core, providing the kernel of stability. Springing from the tower are the three exhibition galleries: concrete tubes that stack on top of each other at various angles like a game of 'pick-up sticks'. A striking woven wooden roof, inspired by a popular Chinese farmer's hat, envelops the entire structure, tying all the elements together and creating a public forum and 22m-high exhibition space for major art installations.

The concept of a timber roof interlaced with planks that weave and stack together, was the brainchild of Arup. It is particularly innovative, providing the designers with a solution to their biggest technical issue on the project. By any account the roof is an extraordinary structure. The irregular, doubly-curved shell measures 90m at its widest and wraps around the buildings below. The hexagons and triangles that make up the undulating curves of the roofwork work in tension and compression as the roof surface varies.

Although Shigeru Ban has a physical approach to architecture and prefers to work with real models rather than with digital simulations, the complexity of the roof necessitated the help of high-tech computer modelling. Arup began by defining the roof geometry from a number of anchor points, using software created to assist the design of tensioned fabric structures. From this a complex calculation model was produced, based on the properties and dimensions of the planks and their assembly. This provided the necessary understanding of how the roof would behave, and how it could be built.

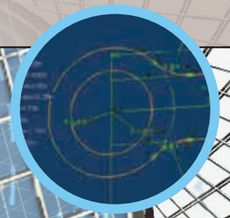
With over 180m visitors, the 30-year-old Centre Pompidou in Paris is France's third most visited monument, after the Eiffel Tower and the Louvre. When complete, its counterpart Centre Pompidou-Metz will provide a new city with an equally emblematic symbol, and become a cultural landmark for the region ■

Project
Fulton Street Transit Center: Arts for Transit Sculpture – Cable Net Structure
Location
New York, New York, USA
Client
MTA Capital Construction

▼ A universal component was modelled using 3-D parametric software, which allowed the design team to ensure its geometry works in all of the hundreds of positions throughout the net.

▼ The model automatically generated stick elements from the complex geometry, shown as coloured lines, that served as the basis for structural analysis.

▼ Parameters such as distances and radii define the geometry of the component in a way that allows for simple refinements to the solid geometry and associated stick elements.



The power of parametrics

With every advance in materials, manufacturing processes and computing power, designers have become ever-more daring and complex in their visions. The centrepiece for New York's Fulton Street Transit Center – a reflective cable net that fills a domed atrium – is one such design that pushes the boundaries of what is possible both aesthetically and structurally thanks, in part, to new computer modelling methods.

bookmark image © Nicholas Grimshaw & Partners Ltd
main image © MTA-CC/NYCT Arup

▶ Currently under construction, the Fulton Street Transit Center will be the focal point of New York City Transit's subway network in Lower Manhattan. Arup is the design engineer for the entire project. The centre's proposed architectural feature is a skewed futuristic sculpture made of cables and panels, designed to fit within the station's central dome. The complexity of its non-uniform geometry was a challenge conceived by the winner of the Metropolitan Transportation Authority's Arts for Transit design competition, James Carpenter Design Associates. It is known as the Arts for Transit Sculpture cable net.

The cable net uses tensioned cables to hold its shape. Each of the 1,000 components has unique stresses. To reduce costs and labour, Arup tested each one virtually before construction, to ensure they would perform under the strain of the hundreds of unique configurations generated by the geometry of the sculpture.

Ordinarily, a structure has an architectural graphic model that represents how it will ultimately look, and a separate structural model to define the performance. With the cable net it was impossible to use existing static 3-D modelling methods, because its overall geometry changed with even minor modifications to the design. Arup's solution was to develop a computer-based design technique that allowed the team to work flexibly and interactively with the model.

Rather than having separate architectural and structural models, which have to be updated separately every time a change is made, the design team linked the two models. They created a relationship between them: when one was changed the other automatically updated. The process couples the techniques of Building Information Modelling with the power of parametric design, so that the individual system components are each defined by their geometry rather than their dimensions.

The design team was able to change a single attribute, such as the length or diameter of a component, and see instantly the impact it had on the entire structure and the hundreds of other subcomponents, each with its own specific attributes. This model could then report the impact of these augmentations on the cable net's performance, down to the most subtle eccentricities.

The new design process validated the design in a way that no other technique made possible. In the process, Arup developed a general methodology for dealing with similar design challenges ■

The project

The new Fulton Street Transit Center stretches over three city blocks and will handle at least 275,000 passenger movements per day, connecting 12 existing lines. Arup has led the design development of the entire project, working with Grimshaw Architects on the architectural design for the main Transit Center structure; HDR Daniel Frankfurt on the modifications of the stations; and Page Ayres Cowley Architects, responsible for rehabilitation of the existing Corbin Building, part of the Center.

Project
Portland Aerial Tramway
Location
Portland, Oregon, USA
Client
City of Portland

Upwardly mobile

Although separated by the Atlantic Ocean, Arup's approach to design innovation links two very different but equally inspiring transport systems. Portland's new cable car Aerial Tram is helping to build a positive future for one of the city's most underutilised neighbourhoods, while Heathrow Airport's ULTra personal rapid transport system brings the world of science fiction one automated step closer.

▸ A spirit of friendly rivalry exists between the three cities of San Francisco, Portland and Seattle on the USA's West Coast. Each places an emphasis on clean living and green transport solutions. But by bridging the divide between two very different communities, the city of Portland has created a sustainable transport system that sets it apart from the competition.

The Portland Aerial Tramway, designed with agps Architects, was conceived to connect the hilltop campus of Oregon Health and Science University Hospital with its new premises downhill along the waterfront. This would provide the adjacent neighbourhoods with a crucial transport link, as a steep elevation and a winding mountain road otherwise separate the communities with numerous busy junctions.

The new Tramway soars up the mountain in just three minutes, at heights of up to 175ft above the ground. The cabins carry 79 passengers at a time, helping to alleviate an otherwise congested traffic area. Arup designed the Tramway's upper and lower stations and its 197ft central support tower, all of which have to endure constant and substantial loads. The most structurally complex engineering challenge, however, came in deciding the form of the upper station and central support tower; the former is located on a steep slope surrounded by existing buildings. The Arup team used 3-D modelling and analysis to test the structures under a variety of different conditions, including the constant and varying forces exerted on them from the tram cables, temperature changes, wind variations and lateral loads.

The 200ft-tall upper station is an open steel structure faced with expanded aluminium cladding. Arup specified a concrete core wall and diagonal steel legs to provide dual structural stability with substantial lateral and torsional stiffness in all directions. The striking geometric form of the central support tower is a result of the forces exerted from its own weight, plus the horizontal tram cable tension loads. The steel construction combines the necessary structural stability with an eye-catching sculptural shape.

The resulting elegant forms provide an efficient, timesaving transport link, and have helped drive investment and renewal in the previously underused Waterfront community. Since opening, the tram has become an iconic symbol for Portland ■

all images © Eric Staudenmaier

Project
Heathrow Personal Rapid Transit System, Phase 1
Location
London, UK
Client
Advanced Transport Systems and BAA

ULTra PRT is the realisation of more than half a century's research into 'on demand' personal rapid transit.

▸ Back with feet firmly on the ground, the future comes a step closer for passengers at London's Heathrow Airport. They will soon experience the world's first driverless and automated taxi service – ULTra personal rapid transit (PRT). It is set to revolutionise how passengers are transported around the airport. Individual pods, each holding around four people, will travel along an elevated 'guideway' between a perimeter car park and Terminal 5 in just four minutes.

The pods are managed by a central control system, ensuring that for the majority of travellers an empty vehicle will be ready and waiting at the station. Passengers will select their destination before boarding and the pod will take them there in comfort at speeds of up to 40 km/hr. Each journey is non-stop. And because the pods offer the privacy of a car, everyone is guaranteed a seat.

ULTra PRT is the realisation of over 50 years' research into 'on demand' personal rapid transit by engineers and transport planners. It is ideal for Heathrow: the visually pleasing guideway can easily be elevated to soar above the ground-level congestion that usually affects new building projects in operational airports. The low-energy, battery powered pods offer significant environmental benefits over cars and buses, as well as lower running costs.

Arup has worked with the pioneer of ULTra for over a decade and has designed the guideway for the project – a slim and lightweight steel structure with a concrete running surface. As the project is a world first, there are no specific standards for this new form of transit, so Arup has drawn on best practice and standards from across the industry to develop a new design code.

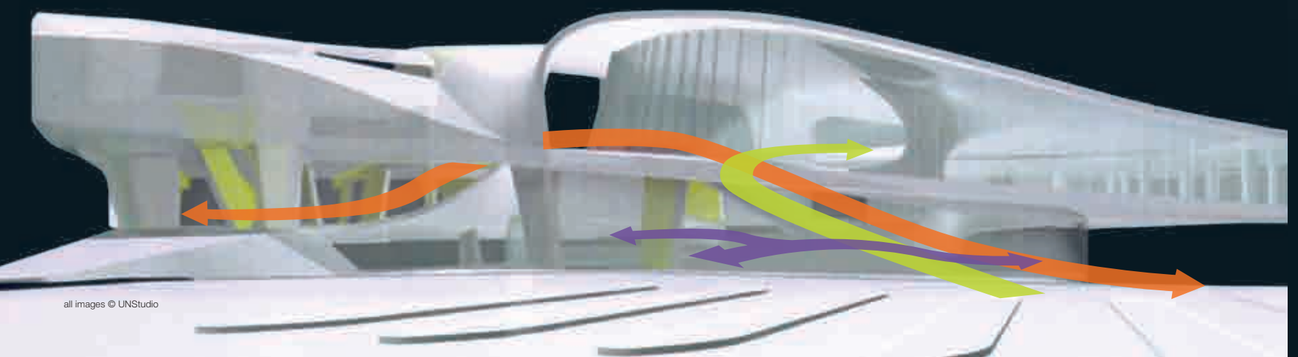
If the trial proves a success, BAA, which owns and operates Heathrow, has plans to extend ULTra across the airport, and city-centre versions are certain to follow. All eyes will be on this interesting project as a potential solution to the challenge of moving people around congested areas more efficiently and sustainably than at present ■

all images © BAA

Project
NSP Arnhem Public Transport Terminal
Location
Arnhem, the Netherlands
Client
ProRail

Transport with a twist

The gateway into the Netherlands' city of Arnhem is undergoing dramatic change. A daring design for Arnhem Central Station's Public Transport Terminal makes use of a unique freeform concrete shape, providing passengers with a smooth transition to different modes of transport. Designed in collaboration with Arup, each structural and lighting element is not only completely integrated into the architecture, but intrinsic to the design's success.



all images © UNStudio

"The development of high density areas requires intense collaboration between the different disciplines and the pooling of their expertise. Arnhem Central is a showcase example of this way of working. As gateways to major cities, these type of infrastructure projects require the highest standards of architecture, engineering and construction."
Ben van Berkel, UNStudio

▶ Arnhem Central Station is a major player in the Netherlands' public transport network, at the centre of many passengers' local and long-distance journeys. It sits on the high-speed rail link between Amsterdam and Frankfurt: 55,000 travellers move through the station each weekday. Six different modes of transport converge at the station, including trains, buses, trolleybuses and taxis. The new Public Transport Terminal is designed so that each can co-exist and complement each other.

The footprint of the site is relatively small for such a demanding brief, so a priority for designers Arup and UNStudio was to develop a masterplan that made the most of the available space. This led to a unique structural design and vertical transport solution with the Public Transport Terminal at its core. By building above and below ground, the surface area of the site was increased from 40,000 to 160,000m². This created room for offices, shops, homes, a new station hall, a railway platform and underpass, a car tunnel, bicycle storage and a large parking garage.

The crux of the design is the striking Public Transport Terminal that will handle the bulk of passenger interchange. Arup and UNStudio have produced a space without columns, which is designed around the people who will use it. The Public Transport Terminal's architectural form will guide pedestrians so they can find their way using only intuition, rather than needing to follow a marked-out route. Passengers will be guided by gently inclined surfaces as they switch their mode of transport. Artificial lighting and shafts of daylight will highlight the architecture and direct people across the terminal's stunning open spaces. Soaring twists of concrete support the long, elegant span of hall and roof.

Consideration of pedestrians played a central role in the design of the terminal. Much time was spent investigating the flow of the station: the way people will move around it, and how they respond to different influences. Moreover, detailed research went into how different transport systems connect with the station, and the way people respond to the architecture that surrounds them. The design team used the findings to create clear lines of vision and short cuts throughout the Public Transport Terminal, to ensure an efficient space and journey.

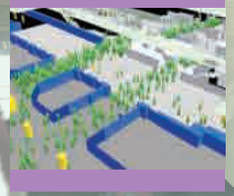
The complex shape of the Public Transport Terminal made it extremely difficult to engineer. Such advanced geometry involved in realising the free-form shape meant the structure had to be modelled in 3-D in order to reach the correct calculations. The geometry of the Public Transport Terminal's striking glass façade also proved challenging. Specialist engineers from Arup were brought in to look at its integration with the rest of the structural design.

Lighting design played an important role in the project. In addition to its obvious functional use in enabling people to move around safely, Arup used light to draw people from space to space, accentuating the various architectural principles and creating a visual reference for visitors to the terminal. The free-form nature of the building meant that the only way to plan the lighting design was to place each proposed light within in a complete 3-D model of the station. Each lamp was programmed with its real-life light distribution; simulations were run to determine the lighting design.

The building's natural light can be seen as one of its greatest architectural assets. Daylight will highlight the sculptural elements of the Public Transport Terminal and at night light will spill out of the terminal illuminating the building.

In 2005, the Arnhem Central Station Public Transport Terminal won the *Schreudersprize* for its innovative, multiple-use, underground construction. The jury considered the client to have shown courage, vision and ambition. The project's underground parking has also been recognised by the Dutch automobile association, ANWB, as the best parking garage in the Netherlands. Arup's multidisciplinary approach helped realise a whole new way of looking at station design, linking architectural expression to human behaviour in a unique and enlightening way ■

Project
Pedestrian simulation of Union Station
Location
Toronto, Canada
Client
City of Toronto



Crowd control

Like ants, commuters are sophisticated, rational movers with an almost perfect knowledge of their terrain. Each working day, 155,000 commuters pass through Union Station, Toronto. Following completion of the current expansion of commuter rail operations, the station expects to handle over 80,000 commuters during the peak morning rush hour alone. Union Station is a complex multilevel transit hub, offering interconnections to a range of further transport and street exits to downtown Toronto. Arup was asked to predict how people would move through a redeveloped Union Station. In seeking the most accurate results, conventional models were rejected in favour of MassMotion, an innovative new software tool. Arup developed MassMotion from a film animation 'engine'. It allows virtual agents to be programmed with human characteristics, producing results that are uncannily lifelike.

▶ The traditional approach to pedestrian simulation is to develop a route network and assign pedestrians across it. This approach is adequate for simpler buildings such as airports, which offer their users only a small number of route choices. Arup, working with the City of Toronto, wanted something more sophisticated and predictive for Canada's busiest transportation terminal, with its multiple and complex route choices. MassMotion is a newly emerging software tool that incorporates agents with individual behaviour profiles and way-finding capability. It was a perfect fit.

A 3-D computer model of the station is populated with virtual agents, who behave – within a narrow range – as people do. These agents are rational and aware of each other. Each has a slightly different behavioural profile. Recognition is harder to programme than reaction: it is relatively easy to instruct agents to walk towards a stair if they recognise it as a short cut, but quite complex to allow them to see it as a stair in the first place.

Even harder is to give agents the ability to evaluate abstractions such as routes with stairs and different levels – precisely how real people respond to their surroundings. MassMotion achieves this. In describing accurately the chaos of the real world it is streets ahead of rival tools.

Early simulations had a certain rigidity, as multiple agents took the shortest route until congestion made it rational to switch. When agents were programmed with more variable behavioural profiles, however, simulations became noticeably more fluid. A recent comparison between real life videos and those produced by the model was uncannily close. Commuters are individuals, but will respond en masse to spatial cues – as MassMotion reveals.

Mass Motion also unmasks the presence of other aspects of human decision-making. Noticing that high activity levels around a particular street exit were not replicated in the model, the baffled team visited the exit to observe in person. Almost everyone who emerged from the exit did so with cigarette in hand: smokers had worked out the fastest exit to above ground. Reality and the model diverged because the behaviour was nothing to do with connectivity – a finding that informed later programming.

MassMotion is a compelling communication tool because there are no abstractions; nothing is hidden. It is a simple enough equation: each peg is a person. Several public advisory meetings have shown that lay audiences accept the science of the model and swiftly focus on key planning and design issues.

The potential of MassMotion is only just emerging. It is capable of predicting passenger movement during a phased construction period, making it a superb facility management tool. It also provides a rigorous basis for evacuation models and could be used in conjunction with fire propagation software or computational fluid dynamics, to help predict responses to future emergencies. Watch this space ■

main image © Arup/Union Pearson Group Inc

Project
Chanel Mobile Art Pavilion
Location
Hong Kong, Tokyo, New York, London, Moscow, Paris
Client
Chanel

In the bag

When Chanel decided to make its legendary quilted handbag the focus of a travelling art exhibition housed in a futuristic pavilion, they called on Arup's innovative designers to realise the vision. The challenge wasn't simply designing a pavilion to meet building regulations in seven cities across three continents – but getting it there in the first place.

▶ The Chanel Mobile Art Pavilion is a spectacular enclosure designed to house pieces by 20 international contemporary artists, inspired by the iconic Chanel quilted bag. The free exhibition, and the cutting edge architecture that contains it, will travel for two years throughout Asia, Europe and the USA, transported between the continents by sea.

Aspects of the pavilion contribute to its use as an exhibition space with much of the artwork mounted directly onto the structure. Therefore, the key challenge was breaking the pavilion down into pieces small enough to fit inside 12m shipping containers for transportation. The team, working with the pavilion's architect, Zaha Hadid, overcame this by creatively remodelling the pavilion structure so that it splits into six-metre sections whose joint lines are incorporated into the design.

In addition to project management, Arup was responsible for the design specifications. To achieve the necessary adaptability and ease of transport, the design team drew on a light, durable material from the worlds of Formula One motor racing and aerospace – fibre-reinforced plastic. The material is increasingly used in construction, due to its ability to hold complex forms. It was an ideal solution for the curvature of the pavilion, and for the ease with which pieces could be sent directly from 3-D modelling to fabrication.

As well as making the pavilion mobile, the team made use of Arup's global knowledge-base in order to design a single structure capable of meeting building codes and regulations in seven world cities. Arup is uniquely placed to help on such matters. It has offices in each host city and internal networks that foster international collaboration.

By tapping the knowledge of the wider Arup family of engineers, the pavilion meets the various seismic, wind, fire, electrical and humidity criteria it faces on its global journey.

Solutions to other problems lay in some surprising places. The contractor responsible for building and touring the pavilion is from the stage-production industry, and as such is well-suited to the task of constructing the pavilion in just three weeks. Working together, the Arup team mastered new techniques for quickly joining the steel structure using pins, hammers and straps – rather than the bolts and welding typically used for permanent structures. In turn, the contractor took away knowledge about new materials and design techniques from Arup that it will adapt to the world of the stage ■

bookmark image 1 © Zaha Hadid Ltd
main image © Piers Shepperd - Ess Staging & Arena Solutions

Project
Condé Nast Light
Spa Cafeteria
Location
New York, New York, USA
Client
Condé Nast

Lighting the way

When techniques more commonly used in monitoring computer traffic were applied to the software behind a new lighting system, the result was illuminating. Alongside system level investigation, Arup collaborated with light manufacturers in developing the emerging, energy-efficient LED technology. The end result is a spectacular, infinite array of colour, movement and lighting options for the Light Spa Café in Condé Nast's New York office.

▸ As you emerge from the elevators within Condé Nast's New York media palace, a series of hidden cameras capture and abstract your image, projecting it along the ceiling and walls of the corridor in which you find yourself. This echo of your image encourages you forward and moves alongside you, accompanying you into Condé Nast's Light Spa Café.

What you find there might be a room apparently drenched in calming daylight. Equally, it might be a pulsating nightclub or a therapeutic spa environment. The space is architecturally lit with over 90,000 light points, consisting of red, green and blue light-emitting diodes (LEDs). Each of these can be individually controlled for 100% dimming, meaning that the system boasts over 270,000 individually programmable lights, wrapping the walls and ceiling.

The LEDs are recessed behind light-diffusing glass, which covers the walls and ceiling of the entire space. The ability to change the LEDs' colour, strength, direction - and even to project video onto the wall - makes it possible to transform mood, colour or visual effect in a second. Indeed, the technology underpinning the Light Spa Café means that the variety of lighting scenarios is limited only by the imagination of its users, who control a lighting system of unparalleled sophistication - all within a staff refectory in a 1960s office building.

When the project was first mooted back in 2005, the client envisaged a lighting system which would lend a spa-like quality to the café area. The client had a background in photography and was unusually aware of light and its effect on people's sense of wellbeing. Running a creative agency, he wanted a flexible space, which would provide an environmental respite from office life. He kept coming back to the uplifting and rejuvenating effect of the New Mexico sunset. So Arup took it from there.

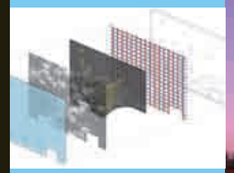
The challenge was to balance the client's ambitious vision with the physical constraints of a 1960s building containing just four inches of ceiling space to accommodate the lights. Arup decided that the best – and most energy-efficient – colour changing solution was to use LED. This was a relatively untried technology, newly emerging in the architectural market on this scale. Combined with the complexity of the site, spiralling cost implications were a risk. Arup found the answers by working closely with LED manufacturers to develop beta versions of the technology. Nevertheless, serious doubts remained as to whether the bespoke software programming needed to control the display was then sufficiently developed. Arup became convinced that it would be possible to apply the kind of techniques used in data traffic mapping to the programming behind the lighting system. This novel approach would deliver a sophisticated and sensitive control mechanism for users of the system. The team knew that it was pushing the boundaries of LED technology: the programming which controls the lighting display remains in 2008 ahead of the market. ▸

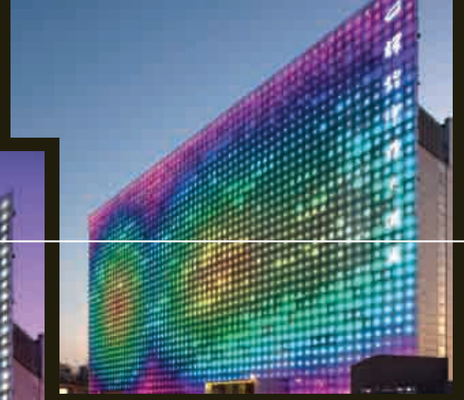
▸ Arup spent considerable time developing the initial lighting scenic concepts and programming. The result was a 'jukebox of playlists', which offered a range of alluring light sequences – including the desired abstract skies reminiscent of a New Mexico sunset – at the push of a button. Arup also provided an authoring tool for people to create their own lighting designs. It works in a visual way that is intuitive to people with no particular technical knowledge, but lends itself particularly well to use by artistic people. It is no coincidence that plans are afoot to recruit a curator for the space. An artistic curator could develop idiosyncratically the possibilities of lighting design, just as the system itself pushes the boundaries of LED technology.

Halfway through construction of the Light Spa Café, Arup's creative agency client became part of Condé Nast Publications, which expanded the stakeholders using the café to 10 times the size of the original group. This meant that establishing a consensus on how the technology should be used became more challenging, while expectations needed to be actively managed.

Ambitions for the Light Spa Café show no signs of slowing, and the involvement of more people in the Café's development has meant fresh ideas and new directions. An inclusive online survey and engagement tool has yielded what is, in effect, a user-group to keep the ideas coming and further develop the Light Spa Café. One such idea is to invite artists to program their own temporary light sculptures. That such a project is conceivable only underlines the sheer flexibility of the new lighting design and technology ■

Project
GreenPix Zero Energy Media Wall
Location
West Beijing, China
Client
Jingya Food Group





Sundown spectacular in West Beijing

West Beijing's GreenPix Zero Energy Media Wall is a triumph of energy-efficient lighting design and engineering. This unique digital media arts venue is a 60m x 33m façade, wrapped around a 10-storey building. It is one of the largest light-emitting diode (LED) walls in the world. Uniquely, it integrates photovoltaic (PV) transparent modules and LED systems: the solar energy captured by day exceeds double that consumed by the lighting. While its excess energy is exported to the national grid, the Media Wall bursts into life after dark, with spectacular moving light displays.

By day, West Beijing residents pass a distinctive glass building façade whose abstract dappled texture suggests light on water. By the time dusk falls, commuters making their way home in the Beijing dusk see a magical giant wall that has transformed into a moving-light installation.

The open-jointed façade incorporates a futuristic lighting system capable of displaying moving images on a 'screen' made up from 2,000 individually programmable LED colour pixels. This is no simple video wall: it is designed with artistic possibilities in mind, and amounts to a digital blank canvas for media and digital artists.

The structure is entirely self-supporting, and has been engineered to comply with Beijing's seismic regulations. It comprises a differently textured mosaic of laminated glass panels. The darker panels accommodate denser PV arrays while the lightest panels contain none. Slight variations in the angle between each panel lend an interesting textural quality to the façade by day.

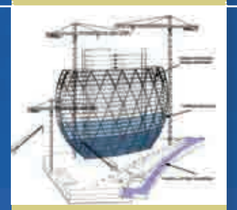
The challenging design called for a subtle interplay of light and glass, suggestive of an indeterminate depth beyond the glass surface. Using sophisticated computer modelling and analysis, Arup and project architects Simone Giostra & Partners were able to develop a combination of glass and lighting involving coloured LED nodes spaced behind the glass exterior. When illuminated at night, the façade would 'de-materialise' and appear to glow. Mock-ups were then used to refine the more subtle and elusive characteristics of the glass.

The original brief to transform an existing building has been achieved in spectacular fashion. Arup's expertise enabled a design that not only showcases the newest technologies in lighting and solar energy capture, but also pioneers their use in a structure that produces twice as much energy as it consumes.

The façade will be launched in summer 2008 with a series of video art installations. The hope is that it will galvanise an energetic artistic community to produce a valued, ever-changing, public work of art that becomes part of West Beijing residents' everyday lives ■

bookmark image 1 and main images © Simone Giostra & Partners/ Arup/Zhou Ruogu Architecture photography
bookmark image 2 © Simone Giostra & Partners

Project
Aldar Headquarters
Location
Abu Dhabi, UAE
Client
Aldar Properties PJSC



Sphere of influence

A perfect circle at the water's edge, Aldar's new headquarters building is the jewel in the crown of Al Raha Beach, an exclusive new city on the outskirts of Abu Dhabi. The elegance and simplicity of the design has already brought the building international prominence – as has the speed of construction. Arup's client was determined to have the building completed by August 2009. The key to meeting this near-impossible deadline has been the use of advanced 3-D modelling and a remarkably close and productive collaboration between Arup and the project team.

Sometimes, superlatives are not enough. This 23-storey circular structure, which will become the new headquarters of Gulf property developer Aldar, looks so simple, so perfect, that it is hard to see where the architecture ends and the structure begins. Indeed, there is no meaningful distinction. The first structure of its kind in the UAE, the building's diagrid concept largely eliminates the need for internal columns, which would compromise both the aesthetic appeal of the building externally, as well as the views from within.

Such simplicity is, of course, deceptive. While conceptually straightforward, the steel diagrid structure is analytically complex. By using 3-D parametric modelling techniques, the design team rationalised the geometry of the structure to maximise the degree of repetition of the façade components. This approach standardised fabrication procedures, driving down costs to levels closer to a conventionally-shaped building. The complexity is in the design process – not the construction. This was made possible by an exceptionally collaborative relationship between Arup, project architect MZP, project manager and main contractor Aldar Laing O'Rourke JV, and the steelwork and façade contractors.

As part of the team's efforts to maximise the building's efficiency, Arup specified a destination control lift system. Another first of its kind in the UAE, the 'intelligent' lift system groups passengers together by destination to deliver them to their office without unnecessary stops. By minimising the space needed for the lift system, these measures have also made a significant contribution to the building's overall lettable area.

The collaborative team approach has allowed the design to be developed and detailed with the most efficient means of fabrication and construction in mind. It also allowed a significant overlap between the design and construction phases: within three months of the design team's appointment, piling work had started on site; the concrete cores were complete within a year. The steelwork was erected up to the fourth floor within 14 months of the project start, even while the designers were still adding an extra floor at the top of the building for the chairman's office ■

main image © MZ and Partners Ltd

The invisible hand

Arup's expertise is a common thread in the design of many signature buildings in the Al Raha Beach development. While Arup's New York team is helping Asymptote architects to realise a stunning spiralled tower, its London team is helping Foster & Partners to deliver a geometrically challenging World Trade Centre, and its team in Los Angeles is working with Hollywood-based 5+Design architects on a complex mix of high- and low-rise buildings. Such consistency from concept through to commissioning can only smooth the delivery of key buildings. Though conceptually they may be very different, all are linked by the guiding hand of Arup, bringing technologies from around the world to benefit each client and project, wherever it is.

Project
The Venetian®
Macao Resort Hotel
Location
Cotai, Macau, China
Client
Venetian Macau Limited

A modern classic

The 3,000 room all-suite Venetian® Macao Resort Hotel represents modern engineering on a grand scale. Inspired by the glorious architectural wonders of Venice, this casino resort's 40-storey hotel opened in 2007, becoming Asia's largest single-structure hotel building. Its scale is immense: the total floor area is around a million square metres. Yet more astonishing is its location, on land reclaimed from the waters between what were once the islands of Taipa and Coloane, and the fact it took a mere 36 months to build.

▲ The use of precast elements made for a tidy construction site and minimal construction waste. It also made for an average construction speed of 62,000m² a month.

▶ With every room booked for its opening weekend in August 2007, the Venetian® Macao Resort Hotel had to meet all its deadlines. The first challenge for Arup's engineers was to take less than six months to plan for the construction to start on a site that was located in a marsh and mangrove area. Soft marine clay is far from ideal ground conditions for construction, and reclaimed land takes time to settle. To accelerate the process, Arup adopted an effective means of speeding up nature's drainage. Vertical band drains were installed in the ground with a drainage layer placed above to capture water.

By adding weight on top – as a cook would weigh down a terrine – the ground was compacted and the resulting settlement accelerated. With this technique, over 95% of the long-term ground settlement took place in four months prior to the construction period. With such a tight deadline to meet, the prevailing conventional construction methods in the area would not have worked. For the Venetian® Macao Resort Hotel, prefabrication for the all-important podium – the lower floors of the development, on top of which the hotel tower would be constructed – was the only option.

The scale of the site was a challenge in itself. The designers adopted large long-span precast units as basic building blocks. At 20m in length and weighing in at nearly 30 tonnes each, they were beyond the capacity of normal tower cranes. A pair of custom-made mobile tower cranes – the largest of their kind ever seen in the region – were manufactured in several pieces and assembled on-site. Tracks were installed within the site so that the tower cranes, rather than being fixed, could sit on wheels and be deployed wherever needed. ▶

▶ Visitors to the construction site marvelled at both its size and its tidiness. It reflected the fact that most of the construction entailed assembling the buildings from precast elements, which eliminated the need for temporary scaffolding and minimised construction waste. It also made for a fast pace of construction – 62,000m² a month, on average.

So far, so good. One of the trickiest parts of the construction process, however, was the façade. Venetian architecture includes Byzantine, Gothic, Renaissance and Baroque elements. The team visited the Venetian® Macao's sister resort in Las Vegas, and studied Venice itself. Statues were laser-scanned and the data were used to make moulds for their reproduction. The task was not to build a replica Venice – though you will find a Doge's Palace, Rialto Bridge and San Marco's Campanile at the Venetian® Macao – but to recreate its streetscape. Capturing the feel of Venice meant casting architectural components like arches, lintels, balustrades, railings and rope mouldings and mimicking its topography, including a lagoon complete with gondolas and, of course, canals.

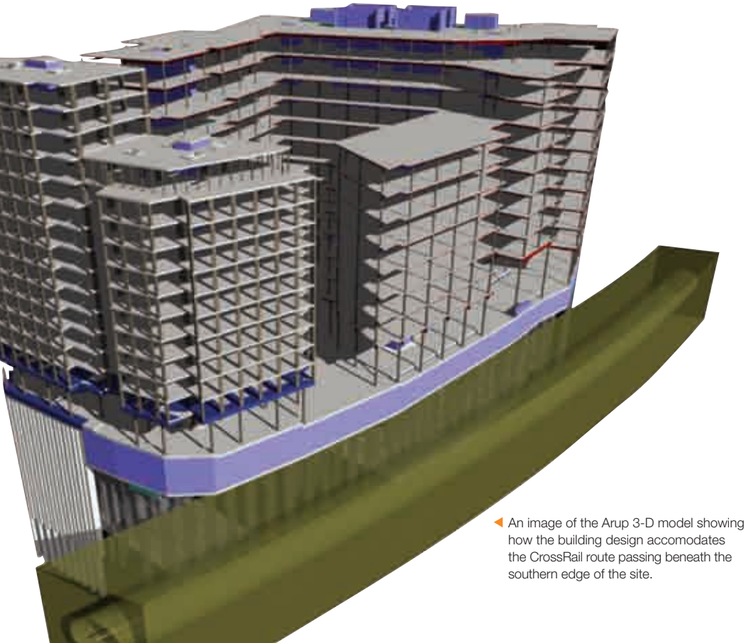
The 150m-long canals of Venetian® Macao Resort Hotel are dedicated to high-end retail. Sophisticated lighting effects combine with the frescoed ceilings to make them, along with the casino itself, the most visited part of the complex. Here, among so many advanced engineering feats, there is still room for some old fashioned artistry. The cloud shades of the frescoed sky ceilings were hand-painted by local artists – in much the same way as the originals were painted, centuries ago, in Venice itself ■

Project
Central St Giles
Location
London, UK
Client
Stanhope plc

What lies beneath

Developing brownfield sites is rarely straightforward. Look beneath the surface of this central London site and you'll find a scheme whose success relies on bringing together Arup's full range of technical skills with modern 3-D design modelling.

▼ Central St Giles 3-D model



◀ An image of the Arup 3-D model showing how the building design accomodates the CrossRail route passing beneath the southern edge of the site.

▶ Saint Giles, a historically run-down area of London's West End, is receiving a major face-lift with a Renzo Piano-conceived design. Comprising a series of 20 ceramic façades that vary in colour and size, this 10-storey, mixed-use development will transform the site of a 1960s Ministry of Defence office block. A vibrant public space will be created, with cafés, restaurants, retail outlets, residential space and offices. While all eyes will be on the vibrant façades, it's what lies under the buildings that made things even more interesting for Arup's structural and building services engineers.

Brownfield sites often present particular structural challenges, but this project appeared to be in a league of its own, thanks to unique environmental and transportation demands. As well as underground parking and bicycle storage, the basement contains a biomass plant that will provide heat for the offices and residential buildings. Green roofs and grey-water recycling boost the project's sustainability performance. However, that meant the main building services plant, including heating and cooling systems, had to be moved below ground, further convoluting a crowded space.

Adding to the site's complexity, the proposed CrossRail underground rail route – another Arup project – passes directly beneath the southern boundary of the site. This has created a three-dimensional tunnel exclusion zone in the exact spot where the building foundations would ordinarily lie. The solution? Reinforced concrete transfer walls to cantilever the building out at the basement level, thus avoiding the tunnel.

Given the high levels of complexity, the Arup team saw value in creating a virtual design for the project – a 3-D environment that allows the complex geometry, congested basement and cantilevered foundations to be designed and visualised in an integrated way.

It was Arup's initiative to pioneer the use of 3-D modelling in this way. The team felt that building engineering is moving towards adopting virtual design as the norm. In 3-D they can quickly tell if mistakes have been made or something does not fit and it is easier to make adjustments. Although the technique has been used before in a number of specialist projects, Central St Giles is one of the first buildings where structural and building services 3-D modelling has been used so extensively from concept stage through to production information.

The project team has worked in 3-D since the start of the project, regularly combining models so that all the information on the building could be visualised in one model. Arup's modelling technicians took the lead in co-ordinating information from the designers that make up the wider Central Saint Giles team. The result is a detailed model that contains the main elements of the concrete and steel structure and a majority of the building services. The CrossRail route has also been included to show how the building design solves this issue.

Most of the engineering drawings for the project, which would usually be drawn individually, have been created from the virtual models and issued for tender and construction. The model allowed the designers to optimise space in the congested basement and test theories quickly and with little risk – because any changes could be easily undone. The ability to produce 3-D fly-through animations that move around and through the site virtually were a beneficial by-product allowing Arup's engineers to visualise the building and solve problems at much earlier stages of the design process.

Another benefit of the model was the ease with which issues could be communicated among the various companies involved in the project, using 3-D to quickly illustrate any problems as they arose. The wider team could accommodate change, increase accuracy and maximise net area within the basement, marking the next stage in the evolution of virtual design as a viable approach.

The models have now been passed to the contractors and are being further developed into the detailed fabrication and installation drawings for structure and building services. By the time Central Saint Giles opens to the public, the virtual model will contain the 'as-built' information as a carbon copy of the real thing and will be an invaluable tool for the future upkeep of the development.

Central Saint Giles has allowed the site's design engineers to use new technology to push the boundaries of what is possible on difficult sites. For the visitors and residents who wander through the finished development, the flurry of activity that fills the new piazza will only hint at the crowded nature of what lies beneath ■

top image © Bovis Lend Lease

Project information

- A mixed-use development containing cafes, restaurants, small retail units, 40,000m² of speculative office space, 53 affordable apartments and 56 private homes.
- The project is jointly owned and funded by Legal & General and Mitsubishi Estate Co. Stanhope is the developer, Bovis Lendlease is the construction manager, Renzo Piano Building Workshop is lead architect, Fletcher Priest is the executive architect, and PRP is the affordable housing fit-out designer.
- The office building will be BREEAM Excellent and will achieve a 20% improvement on minimum Part L energy efficiency requirements.
- Arup is providing structural, mechanical, electrical and public health engineering, fire, acoustics, geotechnics and transport planning for the project.
- Building services were modelled in *CAD Duct* and the structures in *Bentley Structural*. *NavisWorks* was used for visualisation and coordination.

New heights of **achievement**

Building a new visitor centre on the summit of England and Wales's highest mountain takes the concept of difficult sites to a whole new level. It was a challenge that Arup's engineers relished. They set about using all their design experience to help crown Snowdon with a new, iconic, sustainable viewpoint.

Project
Hafod Eryri
Location
Snowdon, UK
Client
Awdurdod Parc
Cenedlaethol Eryri

▶ Building difficult things in difficult places doesn't come much harder than the new café and visitor centre – Hafod Eryri (Upland Snowdonia) – at the pinnacle of Snowdon in Wales. At 1,085m, the mountain – and therefore the building – is the highest in England and Wales.
Its isolated location presented the design team with a huge number of obstacles. No gas, electricity or water supply is on site – and all construction materials had to be carried up to the summit on the rack-and-pinion Snowdon Mountain Railway.

Arup's client, Awdurdod Parc Cenedlaethol Eryri (Snowdonia National Park Authority), was clear that the building should be constructed from local materials, be as sustainable as possible, and showcase the history, poetry and folklore of the mountain to visitors. On a more practical level, the centre will provide weather information, warn about problems on particular footpaths and incorporate a terminal for the railway.

For Arup's structural engineers, the crux of the design was solving the logistics of getting everything up the mountain on a single flat-bed truck. The train journey itself takes an hour-and-a-half, often in high winds, and everything had to be broken down into bite-sized chunks to fit the dimensions and weight limit of the truck. Another big consideration for the Arup team was reducing the time spent in construction on the summit to the bare minimum. There are sheer cliffs on two sides of the building and with the harsh conditions they didn't want people spending time on the roof putting together fiddly pieces. To overcome this, they made allowances in the design for the roof to be prefabricated in larger sections that could just be dropped onto the steel frame. This reduced the time spent erecting the roof to just three or four days. An impressive feat under any circumstance.

Carrillion, the contractor, proposed a trial erection of the structure in a warehouse before building began on site. This meant that the construction team could practise assembling the building in a controlled environment, but also gave Arup's engineers a chance to check that their computer-calculated measurements were accurate. They also used the opportunity to weld together some of the bolted steel beams to help minimise site work. The final frame slotted together smoothly and accurately, saving a lot of time up on the peak.

One of the more interesting design criteria was that the roof of the building must be able to withstand being pierced by a tent peg. A common problem faced by the previous café on the site was summer visitors pitching their tents on the roof, puncturing the waterproof membrane. Thirty centimetres of shale and a thick layer of concrete on the new visitor centre solved that particular problem.

With clever thinking, the team often found themselves solving several issues at once. All of the building's electricity will come from two diesel-powered generators, which by their very nature create a lot of waste heat. Rather than dispose of this heat, Arup's mechanical engineers decided to pass it around the building to provide hot water and space heating. Ordinarily, the building's foundations would have been cast concrete, poured on site. As this was impossible on this particular site, the engineering team designed precast concrete channels, light enough to be brought up by train, that were filled with excavated rock and rubble from the previous buildings. This also proved a sustainable way of tidying up the site. ▶

▶ There has been a fascination with crowning Snowdon with man-made structures, ever since a hotel was first built on the site in 1847. Hafod Eryri replaces the dilapidated brick building that provided refreshments and shelter since 1939. The new centre nestles in the footprint of the old, in order to minimise the impact on the mountain. The geometrically-complicated structure has a long wall of glass that rewards visitors with views across Snowdonia. The entire building is designed to be as transparent as possible so that, from the inside, people can look up toward the highest point; from above, the building appears to be hewn from the mountain.

For Arup, the challenge was one they relished. Hafod Eryri offered them a chance to flex all their design muscles in a once-in-a-lifetime project. Working at a height of more than a kilometre, presented some surreal moments for the Arup team, in particular the sight of the massive excavator being precariously hauled up the mountain. But the greatest source of pride for the Welsh-based team is the vital role they played in making such an iconic project for Wales a reality ■

Project
Heathrow Air Traffic Control Tower
Location
London, UK
Client
BAA

A tall order in a tight corner

Flying in the face of convention, Arup designed a state-of-the-art air traffic control tower that was constructed offsite. It was then assembled in sections on site – from the top down. The world's busiest international airport was a challenging site on which to construct an 87m tower. Huge cranes were out of the question, since they would have meant that construction would have been restricted to the five-hour window during which the airport is closed each night. Arup's approach made a virtue of necessity. And made it look easy, too.

▶ The design of an air traffic control tower is dictated by its function – including its height and the need for an uninterrupted 360° view of the airport. At Heathrow, the new control tower was designed not only with this function in mind, but with a unique installation method as well.

Normally, towers are built from the ground up, as it takes a crane considerably taller than the tower itself to construct the top sections. At twice the height of the old control tower, the new building would have required a 110m-tall crane, which for safety reasons would force construction to take place only during night-time closures.

Arup tore up the rulebook. It designed a structure that could be prefabricated off-site, and safely erected on-site with very little room to manoeuver and without disrupting airport operations. Working with specialist contractors, a jacking system was devised to lift the structure high enough to attach the section below it, then the section below that. This meant building the tower from the top down, starting with the cab, which provides the main space for air traffic controllers. It also meant turning conventional engineering wisdom on its head.

The cab – itself over eight storeys tall in building terms – was built first on a car park a mile from the airport. The completed 850-tonne cab was then lifted and taken to the construction site on a huge transporter.

Arup had to design the tower structure for two load-bearing scenarios – erection and final position – adding considerable complexity to the detailing.

Supported by three jacking towers during assembly, the entire structure was jacked up, and held in position while the next section was slid underneath and bolted in place. The jacking system was then reset at the base of the new section before the process was repeated again until the cab was 87m in the air at its final position. To ensure the stability of the tower throughout the cycle, three tensioned guy cables, themselves controlled by hydraulic jacks, were slowly released as the tower was erected.

The successful construction of this vital building, in the midst of the airfield operations of the world's busiest international airport, was both a design and a logistical triumph ■

Project
Arup Facilities Activation Support Services
Location
Toronto, Dubai, New York
Client
Greater Toronto Airports Authority, Dubai Airports Company, JetBlue

Taking control

Keeping control over any major project through its entire life-cycle is a complicated and highly-pressurised task, with only one chance to get things right. The financial stakes can be high, and with hundreds of different companies and the end users involved, it can also be a logistical nightmare for the managers in charge. Over the course of successfully opening three large airport terminals around the world, Arup's consultants have developed a highly novel set of services for major projects, minimising the chance of 'surprises' on opening day: TCAT, ORAT and eFAST.

While overseeing the launch of the International Arrivals Terminal (Terminal 4) at New York's JFK Airport, Arup developed a comprehensive process to support its testing, commissioning and operational readiness services. Subsequently, while managing the commissioning of Terminal 1 at Toronto's Pearson Airport, Arup noticed key similarities between the complex needs of these huge projects. In short, lessons from JFK would improve the processes being employed at Pearson.

The Arup team used its experience to develop and automate Testing Commissioning Activation Turnover (TCAT) and Operational Readiness Airport Transition (ORAT) procedures. These resulted in a web-based tool called eFAST (electronic Facilities Activation Support Tools). The partnership Arup formed with the Greater Toronto Airports Authority (GTAA) – successfully opening Terminal 1 at Pearson Airport on time and on budget – has led to an ongoing relationship there. The Authority now acts as a consultant to Arup, helping in its projects for Dubai Airports Company and JetBlue.

Design notes

TCAT

TCAT tracks, manages and coordinates the systems within a project to guarantee that they work as designed. It ensures that contractors within a project fulfill their obligations and that the end results satisfy the requirements of end-users. The scope is huge: from testing the mechanical and fire systems, to overseeing the installation of security doors. In the case of Pearson airport, 1,200 separate activities were logged. The outcome is a building that is finished on time and operates as it should.

ORAT

ORAT helps make sure that clients and other project stakeholders are fully prepared to run and manage a facility. Are the right number of people, with the right skills, recruited? Are they trained in all the operating systems? Are operational procedures and contingency plans in place? 'Proving trials' are undertaken, with 2,000 or more people simulating the live operation of the building, testing everything from directional signage to emergency response procedure. Identifying any weaknesses early on, allows changes to be in place before the opening day.

e-FAST

eFAST is a web-accessed suite of tools that facilitates communications between all stakeholders working on a project, driving them towards their common goal of completing the project. Using a simple interface, eFAST allows clients to oversee the TCAT and ORAT processes, view progress, and be alerted when issues arise – all in real time. The system also acts as central database for the entire project.

Project
Tank Street Tensegrity Bridge
Location
Brisbane, Australia
Client
Department of Public Works, Queensland State Government

Suspending disbelief

Tensegrity structure

Almost every bridge design in the world is a modification of a classical design such as the arch, suspension or cable-stayed bridge. Some of these fundamental ideas are as old as civilisation itself. When Arup and Cox Group architects in Australia resolved to find new alternatives, the result was two fresh and original approaches to bridge design: Marina Bay's Double Helix Bridge in Singapore and Tank Street Tensegrity Bridge in Brisbane. In strikingly different ways, they transform that most simple and utilitarian of structures, the bridge, into a thing of beauty – a destination in its own right.

Tensegrity = 'tension' + 'integrity'
The inspiration for the Tank Street structure was sparked by tensegrity, a modern art form and structural system. It is essentially a network of two types of elements: sticks (compression masts) and string (cables). They are arranged in a way such that individual sticks do not touch. The result is a stable three-dimensional structure that appears at first glance to consist of an array of levitating sticks.

A fusion of form and function
More like an art installation at first sight, the Tensegrity Bridge appears to defy gravity, with its 'floating' elements above the walkway. The idea for a tensegrity bridge was the result of a design competition. Arup and Cox teamed up with building contractor Baulderstone Hornibrook, which encouraged and supported the concept from the start. The brief was for a striking river crossing to link Brisbane's central business district with the newly developed Arts and Cultural precinct on the city's South Bank, and the regenerated and rapidly growing West End.

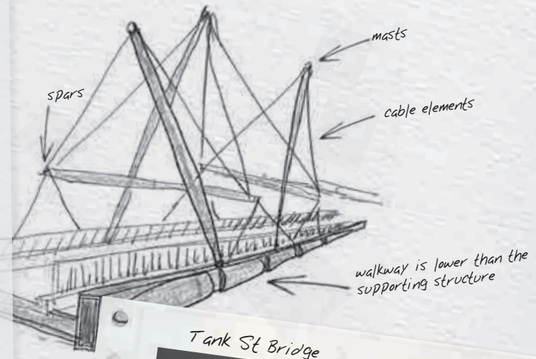
Brisbane residents' taste for striking river crossings had already been established by the success of Arup's earlier, more conventionally beautiful, Goodwill Bridge. Nobody can truly guess what a new bridge will do for a city until it is built: once it exists, it changes a city's layout, bringing diverse areas closer. (The Goodwill Bridge, with a glorious span of 500m, opened in 2001. Since then, its popularity has soared. Now an integral part of city life, Goodwill Bridge is used for three million pedestrian and cycle crossings each year.)

Marina Bay Bridge

Bridge of life
The Arup and Cox design team's earlier competition-winning double helix design for the Marina Bay Bridge, Singapore, was a response to a brief for a single multi-purpose bridge. The team recommended two bridges instead of one: spending less on a road bridge left more budget for a spectacular pedestrian bridge. The double-helix design is based on the structure of DNA. Singaporeans have dubbed it 'bridge of life'. It is, in essence, two coiled springs, one sitting inside the other. They intersect only at the bridge's deck. A network of fine cables delicately balances the forces. With neither truss nor beam, the double helix is fundamentally different from any classical bridge design – it stands as proof that other exciting possibilities exist for bridge design.

Random-looking, but strictly-ordered
The form of the 128m central span is based on a strictly-ordered topology, with major and minor masts. The tops of the masts are scattered in 3-D space to create the illusion of randomness.

Each stick touches only cables



Tank St Bridge

Practicalities

- Height is determined by the clearance necessary for boats
- Queensland's rules on access for the mobility-impaired meant that the bridge had to be very flat, with a gradient of 1:20, the flattest statutory maximum gradient anywhere in the world
- Tropical climate means that pedestrians need shade and shelter from sudden storms
- The integral canopy is facilitated by the spar elements which sit almost horizontally above the deck and are individually suspended only by cables
- The walkway is in fact below the level of the deck beams – rather as the driver's seat of a formula one car is below the wheels

Project
Bat House Project
Location
London, UK
Client
Bat House Partnership

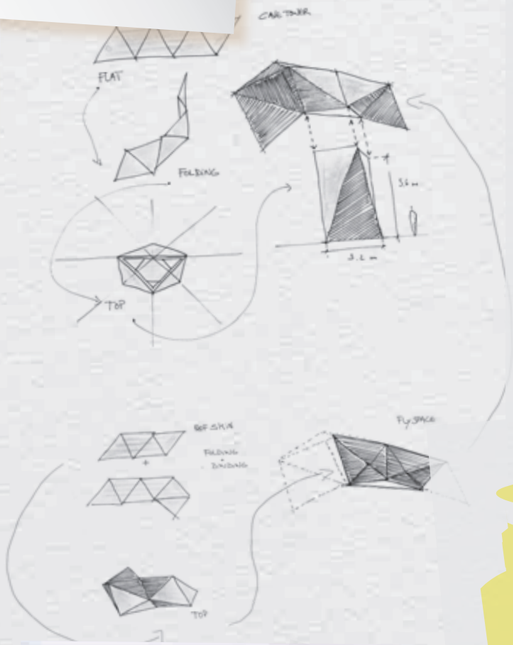
Completed bat house design

Bat wings

London's bat population is under great pressure from loss of habitat as more and more buildings are redeveloped. Jeremy Deller, Turner Prize-winning artist – and friend of bats – teamed up with the Royal Institute of British Architects to create the Bat House Partnership and a competition to design a home for bats at the London Wetland Centre. Arup's highly commended runner-up entry offered an environment suited to the many different species of these winged creatures.

Competition brief
Architects, designers, bat enthusiasts and schoolchildren were invited to submit creative ideas for a Bat House for London. A building of aesthetic and environmental excellence, built with sustainable materials, it is to provide a home for bats and be an educational visitor attraction for people. The Bat House Project partners intend to build the winning design at the Wildfowl & Wetlands Trust's London Wetland Centre.

First sketches
Fittingly, the Arup entry – designed with experts from ecological consultancy Biodiversity by Design and Stefan White Architects – was sketched during a picnic, with the first models built from clay and sticks. The design was inspired by the free flight of bats and considered from conception how the bat house would sit within the landscape. Although it evolved, the final bat house design didn't alter dramatically from these earthy roots, and natural building materials remained core to the design.



Finalising the form

In the initial sketches the form of the roof was irregular. The team wanted to keep this organic feel, but simplified the design to make it possible for the Bat House to be constructed onsite by supervised volunteers.

Nature's building blocks
The body of the bat house would be made from 'earthcrete', mixed from concrete and locally sourced soil, compacted with people's feet. Although it looks complex, the 'attic' structure is simple – made from triangular panels of the same size and shape – and could be pieced together on-site. Cedar shingles coat the northern faces of the attic, while those facing south have passive solar heat and ventilation panels to provide a variety of microclimates and niches for different bat species.

Specialist input
The team's bat specialist helped meet the requirements of different breeds within one design. As well as creating diverse environments within the bat house, the flight patterns of different species were studied. Realising how crucial this was to the design, the team made the landscape around the structure part of its scope from inception.

Visiting hours
Although bats and people have always lived side-by-side, they are not natural 'bed-mates'. The team gave careful consideration to the fine balance between creating ideal environments for the bats and allowing visitors to get close to them. The compromise is a cave within the body of a separate bat house that can hold 10 people, with images of bats projected from within the roofs.

Results

The competition received over 250 international entries, with the Arup project finishing runner-up in the professionals category. Judges praised the design for its extensive research on bats and catering for different species. It was one of only a few entries to show how different species of bats might fly in and around the structures.

Project
Tank Street Tensegrity Bridge
Location
Brisbane, Australia
Client
Department of Public Works, Queensland State Government

Suspending disbelief

Tensegrity structure

Almost every bridge design in the world is a modification of a classical design such as the arch, suspension or cable-stayed bridge. Some of these fundamental ideas are as old as civilisation itself. When Arup and Cox Group architects in Australia resolved to find new alternatives, the result was two fresh and original approaches to bridge design: Marina Bay's Double Helix Bridge in Singapore and Tank Street Tensegrity Bridge in Brisbane. In strikingly different ways, they transform that most simple and utilitarian of structures, the bridge, into a thing of beauty – a destination in its own right.

Tensegrity = 'tension' + 'integrity'
The inspiration for the Tank Street structure was sparked by tensegrity, a modern art form and structural system. It is essentially a network of two types of elements: sticks (compression masts) and string (cables). They are arranged in a way such that individual sticks do not touch. The result is a stable three-dimensional structure that appears at first glance to consist of an array of levitating sticks.

A fusion of form and function
More like an art installation at first sight, the Tensegrity Bridge appears to defy gravity, with its 'floating' elements above the walkway. The idea for a tensegrity bridge was the result of a design competition. Arup and Cox teamed up with building contractor Baulderstone Hornibrook, which encouraged and supported the concept from the start. The brief was for a striking river crossing to link Brisbane's central business district with the newly developed Arts and Cultural precinct on the city's South Bank, and the regenerated and rapidly growing West End.

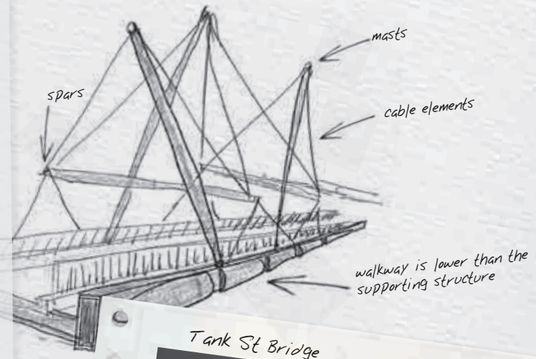
Brisbane residents' taste for striking river crossings had already been established by the success of Arup's earlier, more conventionally beautiful, Goodwill Bridge. Nobody can truly guess what a new bridge will do for a city until it is built: once it exists, it changes a city's layout, bringing diverse areas closer. (The Goodwill Bridge, with a glorious span of 500m, opened in 2001. Since then, its popularity has soared. Now an integral part of city life, Goodwill Bridge is used for three million pedestrian and cycle crossings each year.)

Marina Bay Bridge

Bridge of life
The Arup and Cox design team's earlier competition-winning double helix design for the Marina Bay Bridge, Singapore, was a response to a brief for a single multi-purpose bridge. The team recommended two bridges instead of one: spending less on a road bridge left more budget for a spectacular pedestrian bridge. The double-helix design is based on the structure of DNA. Singaporeans have dubbed it 'bridge of life'. It is, in essence, two coiled springs, one sitting inside the other. They intersect only at the bridge's deck. A network of fine cables delicately balances the forces. With neither truss nor beam, the double helix is fundamentally different from any classical bridge design – it stands as proof that other exciting possibilities exist for bridge design.

Random-looking, but strictly-ordered
The form of the 128m central span is based on a strictly-ordered topology, with major and minor masts. The tops of the masts are scattered in 3-D space to create the illusion of randomness.

Each stick touches only cables



Tank St Bridge

Practicalities

- Height is determined by the clearance necessary for boats
- Queensland's rules on access for the mobility-impaired meant that the bridge had to be very flat, with a gradient of 1:20, the flattest statutory maximum gradient anywhere in the world
- Tropical climate means that pedestrians need shade and shelter from sudden storms
- The integral canopy is facilitated by the spar elements which sit almost horizontally above the deck and are individually suspended only by cables
- The walkway is in fact below the level of the deck beams – rather as the driver's seat of a formula one car is below the wheels

Project
Bat House Project
Location
London, UK
Client
Bat House Partnership

Completed bat house design

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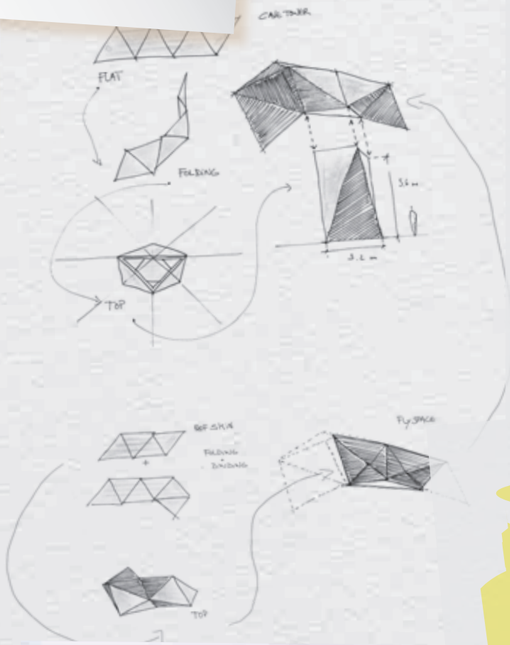

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Project
Yale University Health Services Centre
Location
New Haven, Connecticut, USA
Client
Mack Scogin & Merrill Elam Architects

The SoundLab is adjusted so clients can listen to how a building will behave acoustically before it has even been built.

Listen to your building

Arup is changing the way hospitals are designed, making use of acoustic and visual design tools to improve the privacy of the patient-doctor relationship. Arup's SoundLab – first developed for the performing arts – is transferring knowledge of performance acoustics to the well-being of patients in a busy medical centre.

A team of health professionals sit in a small room, listening intently as an outpatient talks to her doctor about her struggle to stop smoking. As the simulated doctor-patient conversation unfolds, virtualisation technology allows the listeners to hear how the same exchange would be heard and understood in various environments. Realisation dawns on their faces.

The group is from the as-yet-unbuilt Yale University Health Services Center. They are seated in Arup's New York SoundLab, an acoustic and visual design tool that makes it possible to hear and see what a building or environment will be like, before its foundations have been laid.

Prompted by a recognition of the need to improve acoustic performance within hospital environments, this is the first time the SoundLab has been used in a healthcare context. In common with leading healthcare facilities across the United States, Yale Health Services is responding to the Federal Health Insurance Portability and Accountability Act (HIPAA). This governs the disclosure of medical information – including oral communication.

Technical info

- Arup is responsible for the total multidisciplinary design, working with Mack Scogin & Merrill Elam Architects. This includes mechanical, electrical, and plumbing design, in addition to acoustics, audio-visual, fire, IT, and lighting.
- SoundLab is the first 3-D ambisonic listening environment in the industry developed to simulate the built environment.
- This is the first application of the SoundLab within the health care environment.

A dramatic past

The SoundLab is unique to Arup. It was originally developed by master acousticians within the firm, to help them hear how design affected the acoustic qualities of performance venues. The Lab produces an accurate 3-D sound experience that models how different spaces perform acoustically and how the architectural form of a building can affect the quality of sound. It's a radical approach and is the aural equivalent of visualisation. By putting listening at the centre of the acoustical design process, Arup is able to provide clients with a much higher level of confidence in the quality of the final design.

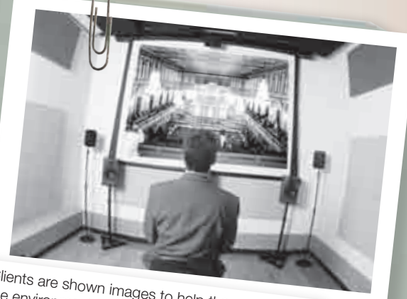
© Mack Scoggin Merrill Elam Architects

All the world's a stage

For the Yale demonstration, acousticians used audio technology to allow the listeners to hear what it is like inside the examination room, then 'moved' them to an adjacent consultation room, followed by a stint in the corridor outside the room. With such knowledge, plus their subjective expectations for the new building, Yale representatives were able to clearly define appropriate privacy requirements in non-technical terms. Arup and its client, the architect Mack Scogin & Merrill Elam Architects, then converted this into a bricks-and-mortar design.

Fine tuning

The new Center will have over 135 outpatient consulting rooms. By letting healthcare professionals listen to how their unbuilt hospital will sound, Arup engineers were able to appropriately optimise the level of privacy in each area, space by space. The level of privacy needed was dependent on the volume of speech normally used in different types of consultation. This varied throughout the hospital: consulting rooms had the greatest need. Staff realised that sick people or the elderly may have hearing difficulties, in which case doctors would need to speak louder. The Health Center also has a Department of Mental Health and Counselling, with counselling rooms where patients may become excitable. Staff didn't want such noise to be off-putting: this area was designed to provide a higher level of sound isolation and privacy.



Clients are shown images to help them visualise the environment they are listening to – inside the consulting room, in the adjacent room and the noise from the corridor.

Pink is better

Given the difficulty of retrofitting existing buildings to become more acoustically responsive, the Yale healthcare staff achieved HIPAA compliance in their previous building using a technique called 'sound masking'. This involved broadcasting a harsh-sounding white noise from speakers located on the floor immediately outside consulting rooms to mask the conversations inside. Although effective, the noise fluctuates drastically depending on the proximity to the speakers. To better blend with the surrounding environment, Arup designed a more friendly sound-masking system for the new Health Center. An array of speakers will be hidden in the ceiling and the sound adjusted based on the principle of 'pink noise'.

Pink noise – which sounds like air or water rushing – is channelled through the ceiling so that the audio quality is uniform throughout the building. It fades into background noise and can be zoned according to which areas need additional acoustic privacy.

Project
Vᵉ
Location:
Valladolid, Spain
Client
Urbespacios

Transport transformation

Design team objectives

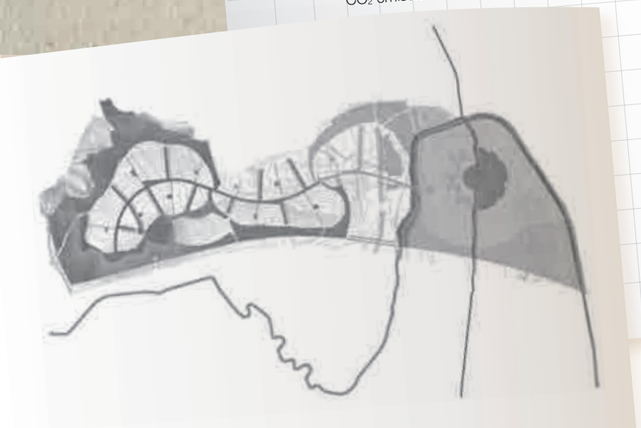
- Establish an alternative model for the growth of Valladolid
- Create a city that re-balances the priorities of access and circulation
- Show that urbanisation and the protection of the environment are not incompatible
- Maximise and protect the edges of the town providing easy access to the landscape outside the city from the centre
- Find an appropriate mix of uses that promotes the sense of community and circulation
- Address the issue of sustainability at all scales

When asked to develop the transport system of a new eco-town for 50,000 people in northern Spain, Arup's designers soon found their remit expanding. In order to get to the root of the town's transport needs, they needed to address the future growth model of the neighbourhood, its integration into the countryside, sustainability, and the structure of the urban area. Their resulting masterplan went straight to the heart of the new community.

When developing a transport strategy for Vᵉ, a new eco-town on the outskirts of Valladolid in northwest Spain, Arup's designers found themselves impacting every element of the 417ha project. The new district of 15,900 homes is being built to cope with a predicted population boom following completion of a new leg of Spain's high speed railway. The new route has cut the 200km journey to Madrid to just 50 minutes. It could be said that the very existence of Vᵉ is due to this transport revolution.

The Esgueva River meanders through the greenfield site where Vᵉ will lie. It influenced the enlightened client, Urbespacios, to approach the growth of Valladolid in an ecological way. Richard Rogers Partnership, working with Arup as the transport strategists, set to work creating a real and vibrant community, rather than a straightforward housing development.

While transport led to the conception of Vᵉ, it was also responsible for the biggest obstacle in designing the masterplan. The design had to deal with the challenge of how to attract people used to living in cities to a suburban neighbourhood five kilometres from the city centre. Moreover, how to do so without increasing a dependence on cars, which would hamper the desired 65% reduction in CO_2 emissions.



Canal del Duero

Flood management

Because the new neighbourhood will lie on the banks of the Esgueva River, flood defences were a consideration for Arup's designers. They came up with an innovative approach involving the main park that runs down the central spine of the town, alongside the river. Working with the landscape architects, Arup designed the shape of the park according to the flood footprint of the river. In extreme conditions, the borders of the park will contain the floodwaters, protecting the city and the Vᵉ neighbourhood from damage.

Best of both worlds

The team played with different uses, densities and concepts of community. In doing so it got to the core of what the value might be in living on the edge of an urban centre. Residents of the new neighbourhood could have the best of both worlds: in less than five minutes' walk from any home they will be able to reach the countryside, local amenities or a bus stop that will take them to the city centre.

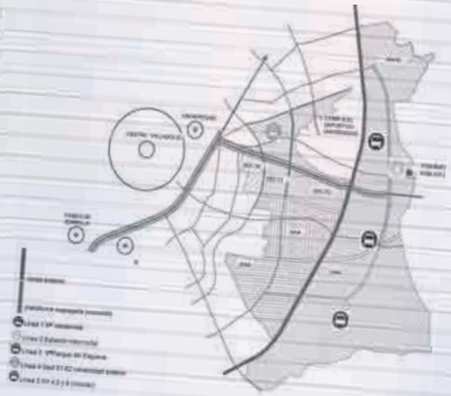
Reducing dependency

An average family in Valladolid makes seven journeys per day, 40% of these by car. The design team's target is to reduce this within Vᵉ to just 25% per family, with the remaining trips undertaken by bus, walking or cycling. To achieve this they designed a compact town with short distances between different centres of activity. If people have jobs near where they live, with government offices, cafés, bars, healthcare and schools nearby, it becomes more attractive to walk or cycle rather than drive. By creating a more densely populated neighbourhood, it is also affordable to operate an express bus service from Vᵉ to Valladolid.

"The regeneration of cities must begin at the centre, but the issue of growth of the suburbs must also be addressed. This project for Valladolid offers a model of suburban development that is more sustainable."
Richard Rogers

Transport hierarchy

The layout of Vᵉ will make using public transport a more attractive option than using a car. One-way systems and segregated bus lanes will mean that within Vᵉ it is much quicker to take the bus, walk or cycle than to drive. Arup proposed a hierarchy of transport movement throughout the neighbourhood. At any intersection where several types of transport meet, priority will be given first to public transport, then to pedestrians, followed by cyclists, and then private vehicles. So, where there is a junction between footpaths and cycle paths, people on foot will be given right of way.



Public transport diagram

Water treatment diagram

Artist's impression

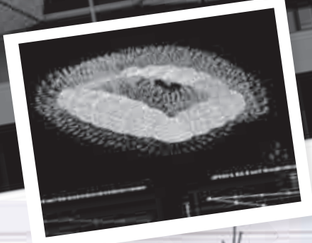
Sustainability objectives:

- Achieve 50% reduction of water demand in homes by:
  - minimising consumption
  - making use of rainwater
  - reusing treated wastewater for watering and ornamental fountains
- Cut CO_2 emissions by 65% compared to standard Valladolid developments
- Design buildings to use less energy
- Use on-site renewable energy sources
- Provide quality public transport to reduce the need for private vehicles
- Adapt the urban area and infrastructure to minimise environmental impact:
  - Density: 100 units per hectare
  - Land use: less than 25% of the total urban land areas
  - Restoration of ecosystem and promotion of biodiversity through parks

Project
Melbourne Rectangular Stadium
Location
Melbourne, Australia
Client
Melbourne Olympic Park Trust

Perfect pitch

If ever there was a sports-mad city, Melbourne is it. A host of international-standard stadia already exists, including the world-famous MCG and Telstra Dome with its moving roof. Its sports fans have historically lacked only one thing: a purpose-built rectangular pitch stadium for football and rugby. The new Rectangular Stadium fills this gap with considerable panache. Arup used the same cutting-edge technology to produce the distinctive 'shell' roof design as it did in creating the soap bubble structural design of the Beijing Olympics' stunning National Aquatics Center. Both buildings are testament to the power of true collaboration between engineer and architect: they combine form with function, beauty with economy. Each is emblematic of the way Arup uses new digital technologies to reinvent the way in which it practises and collaborates with other professionals.



Inside the 3-D parametric model

Shell roof shape is expressed as a key parameter and then related to the key parameter of the curve through the roof leading edge. If the former is altered, the whole model adjusts.

Each new geometrical arrangement is subjected to tests – the first one being spectator sightlines. Where it passes a test, it is modelled with different criteria, and then tested again.

Fit for purpose?

1) Can spectators see 'high ball' from back row?
   - No → rejected
   - Yes → modelled further to optimise structural performance

Bringing costs down

2) How much steel is required? (weight of steel = proxy for cost)

3) What is the minimum possible number of different shapes for the triangulated cladding panels? (standardisation reduces costs of cladding panels)

Judging aesthetic appeal

4) Does it look good? (model creates visual representation of geometry)
   - No → rejected
   - Yes → subjective decision informs modelling process

Melbourne Rectangular Stadium

Design driven by 'sightlines' and 'driplines'

Sightlines and driplines

Modern stadia are all about spectator comfort and excitement. The design of a sports stadium is driven by the need to provide protection from the elements without compromising the spectator 'sightline'. The roof canopy not only provides environmental protection – ideally keeping most spectators behind the 'dripline' – but also has to perform well acoustically. Ideally, it needs to play its part in sustainability, by incorporating measures such as rainwater harvesting. In the case of the Melbourne Rectangular, the roof shelters most of the seats from the elements, yet the design is optimised to consume fewer raw materials.

The repeating shell design is part of a larger roof geometry

Creating a beautiful roof

The design team – Arup and Cox Architects – had the idea of using geometry itself to create a more efficient roof shape. A shell structure was the starting point. It relies upon the principal forces of structural tension and compression for support, in contrast to the external supports and trusses which feature in a cantilever structure. Using sophisticated 3-D computer modelling techniques, the team was able to optimise the repeating-shell design, while also ensuring that it is part of a larger roof geometry. This rises and falls in gentle arcs around the pitch, capitalising on a second, larger series of forces inherent in the overarching shape.

Simplifying specifications

Working out the precise geometry required for the roof itself is just part of what 3-D modelling in an overall digital approach can achieve, when placed in skilled hands. The team was used the modelling techniques to reduce the number of bespoke glass shapes for the cladding system from 600 to 32. This simplified the specification of materials and reduced costs.

The Water Cube
Different look, same technology

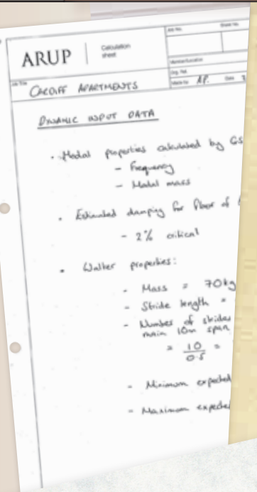
Whereas a shell shape inspired the roof of Melbourne's new pitch stadium, it was the soap bubble that inspired Beijing's National Aquatics Center, dubbed the Water Cube. Both were made possible using tools and design techniques related to 3-D CAD models. Arup, PTW Architects and Chinese partner CCDI, decided to base the Water Cube's structure on the geometry of 'Weaire Phelan foam' – the optimal arrangement of equal volume soap bubbles which is also the most efficient way of sub-dividing 3-D space. Initially, the team made a physical model directly from digital data using ultra-violet lasers – a technique more often seen in manufacturing. To avoid having to make a new physical model for each design change, CCDI created software to generate the entire structural geometry, from the basic size and shape parameters. The entire design process was conducted in a 3-D digital world, start to finish.

NAME
Melbourne Rectangular Stadium project
No.

Project
Oasys GSA Footfall
Location
Various
Client
Various

Design notes

Good vibrations



Software tools originally created to test the effects of footfall vibrations on lightweight bridges and staircases, are proving invaluable in modern building design. Not least as structures become lighter, more flexible and more complicated. Arup engineers found that off-the-shelf packages forced them to fit their problem into a predefined 'type' that didn't give them the detailed results they needed for complex structures. Their response was to work with the firm's internal software house, Oasys, to develop vibration analysis software of their own – the innovative Oasys GSA Footfall (GSA Footfall).

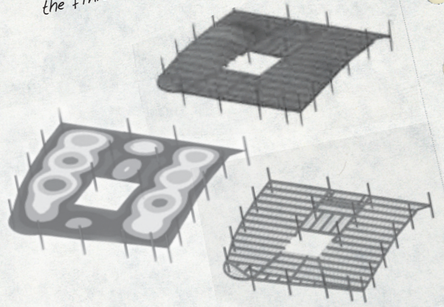
Step by step

Our ability to analyse vertical vibration in structures caused by people walking around is a relatively recent development. Paperless offices and open-plan spaces have lessened loads, while designers and architects continue to experiment with lightweight materials. These factors make floors susceptible to bounce, as people walk around. Although the amount of vibration is usually minuscule – just one or two millimetres – it can be irritating for people nearby. Perhaps more importantly, it can prevent sensitive equipment from working properly in laboratories or operating theatres, for example.

Vibration problems that are picked up early in the design stage are relatively easy to deal with by repositioning equipment, changing the floor construction, stiffening the structure and rearranging columns and beams to reduce vibration levels. Predicting and solving these issues early on is important, as once a building is under construction remedial work is difficult and a lot more costly. Innovation in design and analysis is now used to solve the problems before they are built in.

At London's Heathrow Airport, Arup used GSA Footfall to assess the likely levels of vibration in the new Terminal 5 building. As a result, floor stiffening was kept to a minimum, because informed decisions were made about footfall-induced vibration and the layout of the building – in transitory zones and the location of dwell areas such as seating, for example.

GSA Footfall analysis of the Wallbrook office building in central London identified vibration hotspots that were able to be eliminated from the finished building.



All shapes and sizes

GSA Footfall forms part of Arup's GSA (General Structural Analysis) programme. It allows engineers to analyse any structure, of any shape and in any material, for footfall-induced vibration. Results can be represented in many ways, but most useful for clients are 3-D models of each floor, with data transposed into contour lines. 'Lively' hot-spots are shown in red, fading to purple for the most stable areas. The model takes into account how the vibrations are perceived by a person, and which areas are most prone to movement.

Industry recognition

Arup's GSA Footfall represents a step-change for vibrational analysis. It has been recognised by the Concrete Centre, which adopted GSA Footfall as the recommended approach for analysing floor vibration for its members.

image to right © Hayes Davidson
top right images © BAA Ltd

Project
Global Environmental Aspects Register (GEAR)
Location
Leeds, UK

GEARing up to avoid risk

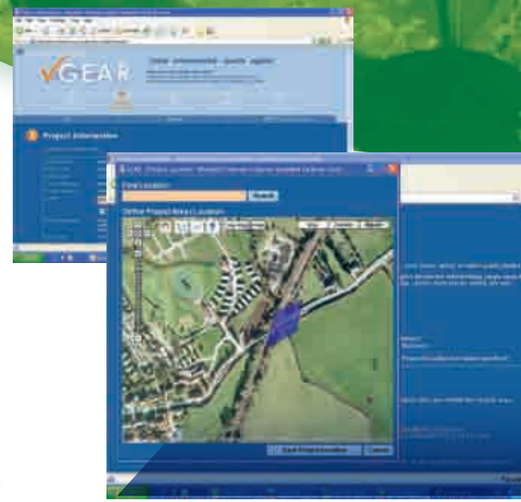
Arup has created a bespoke online tool for its project managers to navigate the increasingly complex area of environmental risk. Using Google Maps™ technology and UK government environmental data, it presents a dynamic representation of a site's environmental hazards and risks. For clients, it provides an early warning of a site's environmental issues that could pose problems at a later stage. For project managers, it eliminates the compliance-driven form filling required at project inception, replacing it with an effective project management, compliance and training tool.

In March 2008, work was halted on a long-awaited £15m bypass for the English village of Earl Shilton because of the discovery on site of a great crested newt. The newt is a protected species under EU law. In another incident, in Doncaster, construction stalled for three months while archaeologists investigated a Roman fort on the site. Such scenarios send a shiver down the spines of budget-conscious developers.

If you know where to look, information about legal obligations and environmental factors, such as local Roman settlements, or whether a site is a likely breeding ground for a protected species, is freely available. Freely available does not, of course, mean easily available. Project managers have long struggled to gather all relevant knowledge and information on a site. Until now.

Arup's novel Global Environmental Aspects Register (GEAR) draws together diverse information sources for clients, designers and project managers. The idea was conceived by a team of environmental and IT experts in Arup's Leeds office. They wanted to improve on what has been a lengthy, less–intuitive, form-filling exercise for compliance purposes.

GEAR allows Arup's project staff to evaluate risks rapidly and to identify key consultation requirements. The result is a better-informed project manager and a far more comprehensive environmental aspects register. It halves the effort, time and cost involved in ensuring that a project is compliant with ISO 14001 and has a clear audit trail. Though restricted to the UK at present, the fact that over 300 investigations were conducted in its first month shows that GEAR is already transforming the way Arup approaches its environmental risk register ■



Inside GEAR

As you log on to GEAR, you see a map view of the site and are prompted with a series of questions, designed to flush out potential on-site hazards as diverse as past industrial activity (potential land contamination) or invasive weeds (Japanese knotweed can break through reinforced concrete). An abandoned building on site might raise prompts to check for bat colonies. Another section will remind you to check the tree preservation order register. Environmental legislation and guidance relevant to the project is also identified automatically. GEAR links to external websites and databases with relevant information, as well as to Arup's own project management intranet, so the information is captured and always available to the project team.

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Project
Interactive flood simulation and flood-risk mapping in 3-D environments
Location
Northwich and Leeds, UK
Client
Northwich Vision/ Vale Borough Council and the Environment Agency

"Northwich Vision considers that this approach to flood modelling has great potential to enable the partners involved in the regeneration of Northwich to identify solutions and effectively manage the flood risk within the town."
Mike Crowther, Senior Surveyor, Northwich Vision

Flood foresight

Around five million people live in flood risk areas in Britain. These risks will increase with changes in climate, including wetter winters and more severe storms. Arup helps people understand the threats using technology that was first used in computer games. The firm has created a powerful tool that simulates flooding and displays flood risk in a realistic, visually-striking and interactive way.

▶ During 2007, England and Wales suffered their wettest summer since weather records first began in 1766. Nearly 50,000 households and 7,000 businesses experienced flooding. Widespread disruption occurred to transport links, power and water supplies. While it will never be possible to prevent floods entirely, better management of land-use and river systems – together with the design of appropriate flood and coastal defences – can greatly reduce both their likelihood of happening and the severity of their impact.

One of the inherent challenges with flood risk management is the difficulty in making the nature of the danger clear to people who have not experienced flooding first-hand. Despite large volumes of available data, flood risk is usually presented using 2-D mapping, making it hard to get complex messages across.

Arup has been working with Northwich Vision and the Environment Agency to assist in the regeneration of Northwich, a market town in North West England that has been severely affected by flooding in the past. To bring the nature of the flood hazard to life, Arup's engineers had the idea of using the latest 3-D computer modelling techniques, perfected in virtual worlds such as Second Life™ and SIMS™, to show moving flood levels in a way that is immediately clear to anyone. The result is Arup's 3-D interactive flood simulation and flood-risk mapping technique.

Using an ordinary internet connection, people can access a detailed 3-D model of Northwich and interact with it, navigating around the streets and landmarks. Simple controls enable them to zoom-in on features they recognise, fly through streets and change their perspective.

Within the model, Arup engineers have used flooding predictions to simulate the way a flood would behave in different circumstances. Users can control the flood to see how it interacts with the landscape and check depth levels at any location. This tool can also be used to simulate and assess the performance of various defences to reduce flood risk: an alternative view within the software uses colour coding to highlight the areas at greatest threat from floodwaters.

Enabling people to see familiar buildings and locations affected by flooding, rather than looking at the same information presented as zones on a map, is highly effective. It encourages a greater understanding of the risks and impact of flood defences. Northwich Vision, the organisation responsible for the regeneration of the town, is using the model as a consultation tool to illustrate the new flood defence scheme it has in mind. Given its ease of access and clarity, the simulation technique could equally be used as a public participation tool or in determining the best way to use land, reducing the probability of flooding in future.

Interactive flood simulation and 3-D flood-risk mapping can be applied to any location using an existing or specially created 3-D urban model. Arup is already working with the city of Leeds on a similar model, to identify the risks to its centre. Given the unprecedented extreme rainfall the UK experienced in 2007, other cities are sure to follow ■

Project
Queens Quay Revitalisation
Location
Toronto, Canada
Client
Waterfront Toronto

Waterfront promenade

Most traffic engineering projects aim to increase the capacity of roads. Arup's traffic team in Toronto together with West 8 + DTAH was given a rather different challenge: to recast Toronto's waterfront as public realm, where it had previously been dominated by traffic. The proposal is part of the area's planned revitalisation, to transform two lanes of a four-lane arterial roadway into a pedestrian and cycle-friendly zone along the waterfront. A family-friendly promenade will link the heritage features at each end of the waterfront, making the location a leisure destination in its own right.

▶ Toronto residents revelled in the 'Quay to the City' event in August 2006, which saw jugglers and sculptors entertain residents and picnickers. Cyclists, joggers and pedestrians made full use of the kilometre-long promenade, created when two lanes of Queens Quay Boulevard on the waterfront were closed to traffic and declared public space.

Unknown to its participants, the event was also a practical experiment in traffic management. By closing two lanes of the roadway, the City of Toronto was simultaneously giving its citizens a taste of what a redeveloped waterfront might be like, and giving Arup the chance to assess the effect of reduced capacity at the waterfront on the city's transport grid.

The team used advanced computer modelling analysis to predict how traffic would behave, and formulate what traffic-calming measures might be needed for the new scheme. The team was then asked to conduct the environmental impact assessment for the project.

Equipped with computer simulations and hard evidence from the 'Quay of the City' event, the team continues to engage the public at a very sophisticated level. Over 300 people attended the last public consultation meeting. The 3-D simulations of the waterfront redevelopment brought it alive for lay audiences. Since so many people had experienced the 'Quay to the City' event personally, it is no surprise that the scheme is enjoying exceptionally high levels of public engagement. It was also a recipient of a 2007 City of Toronto Urban Design Award.

The waterfront already boasts a marina, retail, a cultural facility and new public boardwalks. The proposed scheme improves the current development by tackling its major drawback: access to the historic features of the eastern and western tips of the waterfront, which has historically only been possible by car.

Future generations of tourists are likely to reach the waterfront by public transport. They are the beneficiaries of a vision in which walkers and cyclists are not so much the poor relations among road users, but first among equals. Arup's approach to this challenge is helping to shape a better public realm for the people of Toronto ■

main image

Project
Modernisation and Extension of Plaszów II Sewage Treatment Plant
Location
Kraków, Poland
Client
Municipal Waterworks and Sewer Enterprise in Kraków

Cleansing the Baltic

For decades, Poland's Vistula river has carried effluent from Kraków downstream to the Baltic Sea. The effect of the newly modernised Płaszów II sewage treatment plant, managed by Arup, will be to gradually restore water purity in the Vistula river, and consequently in the Baltic Sea.

▲ Constant aeration of sewage keeps the microbes at peak productivity.

▶ The date is 10 October 2007. A procession of three buses carrying local dignitaries, complete with police outriders, makes its way through the historic city of Kraków in Poland. Tourists crane their necks to find out what is causing the excitement. They might be surprised to learn that the procession will come to a halt at the gates of Kraków's newly modernised sewage plant.

Kraków is now the only major city in Poland that fully treats its sewage. The modernisation of Płaszów II is the largest infrastructure project in Poland and the most advanced of its type in the region. The success of the Płaszów project sets Poland on its way to fulfilling its environmental obligations as a member of the European Union. What's more, substantial EU penalties for environmental pollution have been avoided. The plant employs a newly-patented biological treatment process that is unique in Europe. Funded by an EU grant and a loan from the European Bank for Reconstruction and Development, the project sets new standards in the region. Its benefit will be felt widely: the Vistula flows through both Kraków and the Polish capital, Warsaw, on its 800km journey to the Baltic Sea, whose coastline touches nine countries in Scandinavia and northern Europe. Clean rivers will boost tourism and river life and enhance the lives of all who live along the waterside.

The original treatment plant used an obsolete mechanical treatment process, which discharged high levels of nitrogen and potassium into the Vistula. After modernisation, the plant's existing mechanical treatment capacity has expanded from 132,000 to 656,000m³ per day. A new biological treatment facility, which uses a newly-patented 'cavitation' method to process sewage sludge, has now been built. New sedimentation tanks have been constructed and pumping facilities have been upgraded. The modernisation means that the plant is equipped to perform its task for the next four decades.

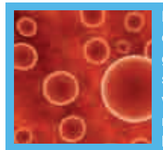
© Jupiter images UK Ltd

◀ The Vistula flows 800km to the Baltic Sea, through Kraków and Warsaw.

The huge project has also enabled Municipal Waterworks Krakow executives to forge close and productive relationships with their counterparts elsewhere. At an early stage, Arup organised visits for key executives to Yorkshire Water's newly-completed sewage treatment plant and sludge incineration facilities in the UK, to see successful international best practice at first hand. The result has been an increased pool of knowledge for industry specialists at a national level. This has contributed to a sophisticated, state-of-the-art solution in Kraków, which befits Poland's recent elevation to a fully-fledged EU member state.

Arup's project team has witnessed the effect of the sewage plant on the environment, and the project manager describes it vividly: "The view from the left hand side of the Płaszów II Plant is of a river that is, in effect, an open sewer; brownish-black and foul smelling. From the other side of the plant, you can look downriver and see the clear water and birds on the river. It's a different world." ■

How does it work?



Raw sewage is subjected to two stages of treatment at Płaszów. First, the rags, grit and primary sludge are mechanically separated from the wastewater. Secondly, wastewater is treated biologically: micro-organisms digest the sewage, to break down toxins, nitrogen and phosphorus into clean water, carbon dioxide and other harmless substances. While the clean water may not be pure enough to add to whisky, it is good enough for fish. The residue following the biological treatment is sewage sludge, which historically has been used in agriculture, although it increasingly ends up in landfill. Płaszów used to feature unpleasant smelling sludge lagoons. Now the sludge will be incinerated on site, leaving only an ash residue that can be re-used as low-grade aggregate in projects such as roads. In nature, one organism's waste is another's resource. Advanced technology allows modern technology to mimic this on a large scale, transforming human waste into something useful for all.

Project
Microclimate Research on Sustainable Planning, Redevelopment of Upper Ngau Tau Kok Public Housing Estate Phases 2 & 3
Location
Hong Kong (HK)
Client
HK Housing Authority, the Government of HK Special Administrative Region

Named after the incense and scented wood products that were once traded there, 'Hong Kong' translates literally as 'fragrant harbour'.

Helping a city to breathe

For skyscraper lovers, Hong Kong is the place to go. Its skyline boasts 7,681 of them. Such density of high-rise development creates profound ventilation challenges in a tropical climate. A shift of thinking in building design is recasting Hong Kong's coastal winds as a precious natural asset, to be exploited and protected for the benefit of all.

▸ Land shortages in Hong Kong have driven high-density development. For those who can afford it, luxury high-rise apartment blocks on the seafront are favoured. But nearly 50% of Hong Kong's residents cannot afford a private residence. For them, Hong Kong's Housing Authority provides public housing. The challenge for public and private sector alike is to maximise space, and the solution for both is the same – to build skywards. The high-rise buildings themselves exacerbate the city's problems of humidity and heat in a tropical climate. Indeed, the clustered waterfront skyscrapers act as a windbreak – depriving buildings further inland of cooling breezes. Arup is addressing these issues. It is actively participating in the evolution of Hong Kong's new public housing design, and has worked on over 30 of its public projects.

To improve the environment for all, the answer lies in a microclimate approach, where external space is designed to take advantage of natural ventilation, avoiding intense solar radiation. Typical public housing comprises clusters of between five and 15 blocks. Arup introduced computational modelling techniques to design with more flexibility both buildings and estates.

Designers can now optimise the design or configuration of buildings, pulling blocks wider apart or pushing them together on screen at an early stage. This site-specific approach allows them to orient the buildings and position the façade to minimise solar radiation and maximise the wind benefits.

Historically, Hong Kong's public housing design tended to favour the space-efficient cruciform shape. The major drawback is that it can be harder to address the environmental characteristics of individual sites with this standard built form, resulting in a lower level of sustainability. Hong Kong's planners are actively seeking alternative design approaches; Arup is assisting.

With more than a fifth of Hong Kong's public housing residents over 60 years old, designers must also prioritise social considerations such as better access. Buildings need to promote health and social interaction. One way of doing this is the microclimate approach: providing well-ventilated, shaded and landscaped space such as open space shaded with tree or canopy and 'sky gardens', drawing people outside.

However, the microclimate approach is still relatively rare among local architects and planners. Arup is changing this. Each year the firm talks to the International Housing Congress and puts on local seminars to help promote understanding of current techniques and approaches. Arup is involved with around six public estates at any time. Each project is an opportunity to develop and refine further a site-specific approach to public housing. The first public housing estate of this type, designed with microclimate approach by Arup, is the Redevelopment of Upper Ngau Kok Estate Phases 2 & 3. Taking account of local site characteristics, the estate is designed to maximise the potential for natural ventilation, use of natural light and energy saving to dwellings, and to improve the quality of both indoor and public open spaces. The provision of a wind corridor and cross-ventilated re-entrants, for example, gives the buildings greater permeability. The Estate will be occupied in late 2008. It marks a significant step in developing a different kind of approach to design in Hong Kong ■

Project
Urban Climate Map, Air Ventilation Assesment Project
Location
Hong Kong
Client
Public and private sectors

Meanwhile, Hong Kong's air quality is deteriorating. The effects of pollution from the heavily industrialised Pearl River Delta region on the Chinese mainland, plus the island's own power station, can be keenly felt.

▸ Enhancing the city's ventilation has never been more important. The Hong Kong Government recognised this with its recent Air Ventilation Assessment (AVA) building guidelines, which apply to public buildings and which may in time affect private sector development.

Through its work on the majority of Hong Kong's public projects that require an AVA study, Arup has developed a way of mapping air ventilation in urban areas, in order to optimise urban design.

For three years now, Arup has worked closely with the Chinese University of Hong Kong on this project. The technology is similar to computational fluid dynamics. It allows Arup's consultants to identify wind corridors in cities, and helps to achieve optimum wind ventilation in building design with measures such as enhancing buildings' permeability by introducing cross-ventilated corridors at points of entry and exit. It also shows how building orientation can be modified to improve ventilation at pedestrian level.

The conventional turbulence model cannot adequately represent turbulence on a city-wide scale. The more sophisticated 'Large Eddy Simulation', is too time-consuming for practical applications in the built environment. Arup is developing an innovative hybrid method, namely a 'Detached Eddy Simulation'. This is the best of both worlds: more accurate external wind environment predictions, combined with practical viability ■

Project
Study on Parking Demand for Public Housing Developments
Location
Hong Kong
Client
Hong Kong, Housing Authority

Freeing up space

Urbanisation pressures are intense in Hong Kong. The limited supply of land for public housing means people can expect to wait an average of three years for an apartment. In recent years, to the concern of Hong Kong's Housing Authority, accommodation demand has been accompanied by an increasing number of empty car-parking spaces. Since multi-storey car parks cost almost as much to build and operate as apartment blocks, persistently unused car parks are a sign that public money could be better directed to meet housing needs. Arup took a rigorous, needs-driven approach to studying parking demand, quantifying it by development type. The study paves the way for a more flexible, nuanced approach to Hong-Kong-wide parking standards, which can liberate unused space for accommodation.

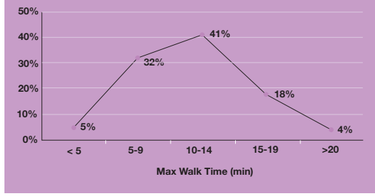
▶ In many cities around the world, finding an empty parking space is a major cause for celebration. In a city such as Hong Kong, where the pressures of urbanisation are so high, large numbers of unused parking bays in public housing developments often show that public resources are being underutilised. Put simply, money could be better spent on increasing the amount of housing, rather than on under-used car parking spaces. With public housing parking provision set at a strategic level by Hong Kong's Planning and Standard Guidelines, the Hong Kong Housing Authority asked Arup to study parking demand. Arup was asked to identify alternative approaches to parking standards in the territory, ultimately increasing the space available for housing.

Arup took an innovative 'bottom up' approach to the study, basing it on a large-scale household survey that firmly placed it in the real world of subsidised housing. It complements the territory-wide approach to parking demand for private and public development, which Arup developed separately in a previous study. Public housing residents from every single public housing estate in Hong Kong participated, creating a truly comprehensive picture of parking demand. The survey exposed significant variations in parking demand across districts, demographics, and income levels. Occupancy levels, for example, ranged from 10% in rural areas of the territory to close to 70% in urban areas. Plainly, a 'one-size-fits-all' approach to parking provision would not do.

Compared to the territory average, the lower-income profile of public housing residents was reflected in their preference for motorcycles. This led to Arup recommending a change to the ratio of parking provision for motorcycles, against other vehicle types. Similarly, a greater number of elderly, non-driving residents in smaller housing units accounted for the lower car use in developments with smaller apartments. As a result, these developments are exempt from the requirement to provide parking ■

Factors affecting parking choices

Many factors affect the take up of parking spaces. Proximity is important: over 70% of people found that their car parking provision was accessible. This graph plots people's willingness to walk to parking provision as captured by the survey. The average maximum time people will spend walking is nine minutes, beyond which they may defect to on-street parking and stop using their own provision.



Project
San Francisco Federal Building
Location
San Francisco, California, USA
Client
General Services Administration

Light and airy

If you need proof that a holistic approach to design can provide comfortable, energy-efficient working conditions, look no further than the new Federal Office Building in San Francisco. Oriented to capitalise on coastal winds for natural ventilation, the concrete building is shielded from direct sunlight by a 'skin' made of rotating perforated metal panels. The slender 18-story tower sets new precedents for performance-based design in the USA's public sector.

▶ In the heavily codified United States building industry, natural ventilation is barely acknowledged as a design option. However, the United States Federal Government's Design Excellence programme has always viewed its own buildings as opportunities to try new approaches. It was open to Arup's proposed performance-based initiative, in which the building design was subjected to a series of earthquake simulations. Such an approach exposed how little additional safety benefit would be provided by a secondary seismic system – as demanded by the codes. It demonstrated that the better option was a main structural system, augmented with slightly more reinforcing steel.

The site's natural resources informed the building design: the team examined local temperatures, wind direction and sunshine data just as closely as the city's planning records and the urban context. At 275ft high, the Federal Office Building is over twice the height of its height-restricted neighbours along Market Street, ensuring permanent access for the building to the prevailing northwesterly cool winds during the summer.

Instead of steel construction, Arup recommended concrete for its inherent strength and thermal mass. This characteristic is crucial to the natural ventilation concept, as it allows most of the building's occupants to sit within 20ft of windows. The building is slender – just 66ft wide. The central portion is given over to areas requiring sound privacy, such as supervisor offices and conference spaces, as well as elevators and essential comfort facilities. Security concerns necessitate that the first five floors are sealed and conventionally heated and cooled, making them the ideal locations for computer servers and rooms with high heat load. Exposed concrete ceilings, columns and walls absorb heat like a sponge during the day, releasing it at night. Façade elements release warm air from within by day and allow cool night air into the building at night, which cools the concrete surfaces.

Naturally lit and ventilated spaces can feel different to people used to air conditioning. The absence of the low-level background hum, for example, means that voices carry further. Thus, light fixtures are outfitted with speakers that transmit white noise to compensate. People control their own windows and internal shades to avoid glare, and ambient lighting automatically dims in response to available daylight from the glass façade.

The building, designed with architects Morphosis and The Smith Group, represents a new approach to integrated design. The team awaits the formal Government-sponsored post-occupancy evaluation, in 2009, with barely concealed excitement. Comparisons between the comfort of people on the air-conditioned fifth floor and those on the naturally ventilated sixth, immediately above, will be of particular interest.

The San Francisco Federal Office Building shows how a holistic, site-specific approach can produce a perfect fit between a building and its location. Yet the design methodology, which starts with a site's natural resources, can be used anywhere. In the hands of skilled designers, a more flexible alternative to the prescriptive, codified approach to building design may prove increasingly important for a changing future ■

Project
WWF Headquarters Building
Location
Zeist, Netherlands
Client
World Wide Fund for Nature in the Netherlands

Living space

Can a building itself further the charitable aims of its occupants? The World Wide Fund for Nature (WWF) in the Netherlands has achieved just this. WWF addresses global threats to people and nature, such as climate change and the unsustainable consumption of natural resources. Its newest national headquarters embodies its work, achieving carbon neutral operation and providing an educational and promotional tool for encouraging interest in low-energy sources and 'One Planet Living'.

▶ The new Dutch office of the WWF is one of the most sustainable office buildings in Europe. WWF chose a woodland site and opted for refurbishment over new-build, with sustainable materials. All this is entirely consistent with the charity's broader goals of promoting conservation and protecting the natural world. The distinctive building draws visitors in its own right, and has stimulated interest in – and coverage of – low-energy technologies.

When WWF decided that it needed a new Dutch office, having outgrown its former building in Zeist, it chose to view its relocation as a positive opportunity. It wanted to show that a building could be built with minimal damage to nature during its construction and operation. It wanted an exemplar of low energy and renewable technologies, and ideally a building that would prompt others to explore and adopt such technologies. However, as a charity WWF had a strict budget within which to achieve its objectives.

Having identified a disused laboratory building near its original headquarters as a suitable refurbishment project, WWF asked Arup to work out which technologies would work best with the existing structure, to deliver near carbon-neutral operation with limited funds. Such an aspiration is notoriously hard to realise with an existing building, since the structure itself was built with other objectives in mind. After the initial design had been completed, WWF won a further grant for the building, enabling Arup to lower the carbon footprint still further. Charged with building services engineering design for the project, Arup analysed the trade-offs between capital cost, operational cost, fuel and resource use, carbon footprint – and even opportunities for resale of surplus electricity to the national grid. From the outset, Arup worked with the existing structure, rather than against it, aiming to re-use materials wherever possible. The priority was to minimise operational costs by using low energy and renewable technologies.

The approach taken to the building's climate control was a first in refurbishment and a study in inspired improvisation: the existing structural mass was utilised as a means of lowering the building's energy needs. The Arup team suggested that mats of plastic pipes be plastered to the underside of the structural slabs, in order to harness the existing thermal mass to create a post-fixed cooling system. The heating and cooling is provided by a ground energy system, heat pumps and free cooling modules, achieving superior energy efficiency.

A hybrid ventilation system, which incorporates pressure-controlled natural vents in the façade, enables occupants to control ventilation. This reduces fan energy and space take in the building. A combined heat and power plant, run on biofuel, further reduces the building's carbon footprint. Solar water-heating saves yet more energy, while water use itself is minimised, and, where possible, recycled ▶

▶ The close relationship between the charity's aims for the building and its wider charitable aims in preserving the biodiversity of the environment, including all species of flora and fauna, raised some contemporary sustainability issues. WWF realised the potential contradiction between using biofuel to reduce the building's carbon footprint and the wider question of the biofuel industry's soaring demand for land for crops, with consequent loss of animal habitat. Arup's expertise in sustainable design meant that WWF could draw on the global firm's collective experience. Arup helped WWF to analyse the issues clearly, and sanction the use of biofuels as but one of a number of solutions to reducing reliance on fossil fuels in the building operation.

Today, at WWF's new headquarters, the energy performance of the building is not merely documented, but publicised, with an educational display planned for the building's reception. Displaying the building's energy performance itself means that, for staff and visitors alike, the core philosophy of the WWF, and its commitment to preserving wildlife and its habitat, is neither out of sight nor out of mind ■

Project
Nokia China Campus
Location
Beijing, China
Client
Nokia (China) Ltd

Leading the way

When Nokia started planning its new headquarters and research facilities in Beijing, it insisted that Arup was involved from inception. The resulting creation has attracted attention all around the world. It is the first newly constructed commercial building in China to be awarded a Leadership in Energy and Environmental Design (LEED) Green Building Rating System™ Gold certificate by the United States Green Building Council. From day one, Arup put together a global team of its experts, enabling a quick build-time and the total integration of all the building's systems. The approach to what is one of China's greenest office buildings will be utilised by Nokia in all of its new buildings globally.

▶ The 'Nokia Green Building', as the telecommunications company's new 70,000m² headquarters in Beijing is known, is a striking example of sustainable design principles and energy efficiency in China. Not only does it consolidate Nokia China's operations – providing office space for 2,000 employees and a research and development (R&D) centre – it serves as a model for Nokia's future approach to its building stock around the world. Its award of a LEED® certificate reinforces this approach and presents others in China with a model for how modern office developments can contribute to a country's progress on sustainability issues.

The importance of Arup's involvement cannot be underestimated as it provided total design for the project with Arup Associates creating the initial concept. This encompassed everything relating to the design and build, aside from interior design, project management and the actual construction of the building. Sitting around a table with Nokia from the very beginning of the project created many advantages. Because the building is aimed at end-users, Arup could define the client's requirements early and feed them into the design brief. This made the process much quicker than a more conventional approach, which would typically involve consultants from multiple organisations variously informing a design brief.

With its broad skill-set, Arup was uniquely placed to deliver all the design and technical support to the building. Using the firm's global knowledge networks, Arup created an international team for the project, led from Beijing. Masterplanners and architects in the London office worked with architects, structural engineers, electrical and mechanical engineers, acousticians, sustainability experts, fire engineers, traffic planners, lighting engineers and other specialists, located in Hong Kong and throughout mainland China. Having responsibility for so many areas of the design process meant that Arup could move the project with great speed – a distinct benefit to Nokia. This resulted in a quick turnaround project: it took just 26 months from initial design to occupation.

The sustainability design strategy for the campus responds to the climatic conditions of the area, making use of natural light and ventilation, and using recycled materials wherever possible. Through the use of conservation devices, double-layer glass walls and many other design techniques, water use in the building is reduced by 37% and energy consumption by 20% – as compared with business-as-usual commercial buildings in the West.

Skylights and a large communal atrium provide natural light and ventilation throughout the building – as well as a lively canteen for staff. The headquarters has underground parking, a reserved parking area for environmentally friendly cars, and a secure bicycle parking area to encourage motor-free commuting.

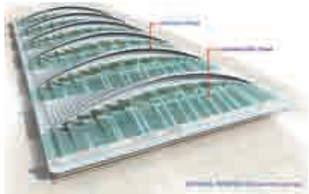
The glass façades of the six-storey building have a temperature-controlled cavity between the panes. This works with the sun's natural heat, and the building's air-conditioning system, to prevent the impact of outdoor temperatures being felt inside. The team used advanced building physics to analyse the way materials would perform on the site, in order to determine the most appropriate solutions and reduce wastage. So, while the east, west and north façades all require an inner and outer skin, the orientation of the southern wall meant that only a partial outer-skin was required to achieve the same level of performance.

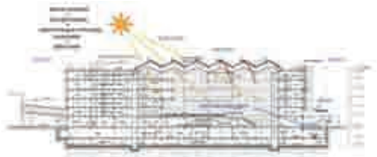
The building design gives equal consideration to the well being of staff. Over 97% of the building provides an outside view. And with a gym, nursery, community centre and social spaces, employees are at the heart of this new headquarters. Because of the weight of the equipment used, the R&D space had to be located in the basement of the campus. Instead of the typically sterile R&D environment, Arup designed a sunken garden at the perimeter of the R&D space that is served by natural sunlight, greatly improving the staff environment.

That the building has been awarded a Gold LEED® rating is a welcome validation for the approach taken by Nokia and Arup with the design of this new campus. It sets a standard for environmentally sustainable construction in China and should encourage wider adoption of new sustainable green building and development practices – all around the world ■

▲ The double 'curtain wall' system consists of an internal double-glazed unit, a single-glazed external skin and a controllable ventilated cavity.

▼ Thanks to skylights – which are the main feature of the building envelope – energy efficiency is achieved even with a large portion of the façade being glazed to allow external views and daylight to penetrate. The skylights occupy 12% of the total rooftop and are particularly efficient. For the portion of the roof that is opaque, aluminium cladding with polyphony insulation board is used to reduce the heat transmitted.





▼ The external skins are mainly installed on the east, west and north elevations with partial coverage on the south elevation from level 2 onwards. The outer skin of the double-skin façade uses spider fixing. Fritted glass (ceramic painted glass) allows a degree of transparency while at the same time providing shading to reduce heat gain. The smooth façade prevents attachment of dust – a serious problem in Beijing.

▼ The internal curtain wall provides thermal insulation, protection and ventilation. The internal skin consists of double glazed low-e tempered glass and a powder coated anodized aluminium transom and mullion. The curtain wall is set on the building gridlines. Thermal insulation material is used for thermal protection enclosed by powder-coated aluminium cladding panel.

Project
Citigroup Data Centre
Location
Frankfurt, Germany
Client
Citi Data Centre

It is estimated that the facility will:

- Save 11,000 tons of carbon dioxide emissions
- Cut energy use at the site by 75% – enough to power 3,000 family homes for a year
- Reduce water use by 12m gallons
- Achieve the first ever Gold LEED® rating under the US Green Building Council's LEED® standards for a data centre

Against all odds

Is an environmentally-friendly data centre a contradiction in terms? After all, data centres account for 2% of the world's carbon emissions – twice that of the entire UK. In green terms, they have been shrugged off as something of a lost cause. Work with Citi, the global financial services company, is changing the status quo. Citi made sustainability an integral part of the brief for its latest data centre in Frankfurt. The building is anticipated to achieve a LEED® gold rating – a world first for this sector.

▶ From the start, this project had twin objectives: achieving the reliability and resilience that is essential for business continuity in any data centre, while creating a rigorously sustainable, low carbon-emissions, built environment. Working across international boundaries, Arup Associates brought together Arup's data centre experts and local collaborators in Frankfurt. The designs exceeded demanding reliability criteria, and reduced carbon emissions by 70%, through a rigorous process, where all aspects of the building were considered. This included the building's cladding system, which incorporates timber shading for the offices, enabling them to be naturally ventilated and day-lit. The end result is both an award-winning design – and the greenest data centre ever built.

Architecturally, the landscaping as well as the structure itself is integral to the design. A 'living roof' covers the roof surface, minimising thermal gain during summer and introducing biodiversity to the site. It also captures water, which irrigates a 12m-high 'green wall', planted with indigenous species and providing nesting habitats for a variety of birds, as well as absorbing CO_2 emissions.

The design team aimed for a realistic, scalable and replicable approach, avoiding token measures. The entire decision-making process was subject to ISO 14001 and the LEED® framework. Pending final approvals, the data centre may even achieve an exceptional LEED® Platinum rating. By engaging with the most demanding and energy-hungry building type in this radical way, the project team has taken the sustainability agenda to the heart of the financial services and technology industries. It is here that a genuinely significant difference can be made in reducing global carbon emissions ■

Project
Applied Research and Development Building
Location
Flagstaff, Arizona, USA
Client
Northern Arizona University

Project facts

- 62,000ft² mixed-use building
- One-third of the building is built of recycled content materials
- 89% less regulated energy consumption than a typical building
- Over 50% of building's electricity provided by solar power
- 160 kW of electricity produced by PV panels
- 92% of construction waste was diverted from landfill
- 90% reduction in potable water use

A flagship for Flagstaff

Visitors to the mountain town of Flagstaff remark on its pristine air, historic charm and proximity to the Grand Canyon. They might be surprised to learn that Flagstaff's Northern Arizona University (NAU) campus also occupies a place at the vanguard of sustainability. Its new Applied Research and Development Building won LEED® Platinum status this year, with 60 out of 69 available points – one of the highest scores ever achieved. This sophisticated building accommodates high-specification research laboratories, a networking hub and learning space while reducing regulated energy consumption by a staggering 89%.

▶ When the NAU's vice president of capital assets was directed by the NAU president to visit one of Arup's UK projects at Nottingham University, it was the start of something. He returned with the conviction that such sustainable design could transform the NAU's own campus, setting new standards in sustainability. The design team responsible – Hopkins Architects, BWS Architects and Arup – was invited to submit a competitive tender for the NAU's new Applied Research and Development building. The building would need to combine high specification laboratories with public and learning space.

The challenges were considerable. Unlike many private universities in the United States, NAU is publicly funded and must attract and support both researchers and students to thrive, so the budget was limited. The design team avoided the 'study unit' approach often seen in research institutions: the building's openness and transparency fills the building with light and affords stunning views of the surrounding mountains. The working environment is both inspired and inspiring. Communication, openness and the exchange of ideas are encouraged by the very design of the space. Like its dramatic location and mountain backdrop, the building itself is beautiful, with an overarching glass gallery along the south-facing façade, which seems to bring the outdoors inside.

At 7,000ft above sea level, Flagstaff enjoys temperate summers and cold winters. The building was oriented due south to capture the winter sun's heat. At the front of the building, a three-storeyed glass gallery floods the building with light and provides a thermal buffer for the offices behind. The building's structural frame provides thermal massing to retain heat in winter and cool it in summer; these passive systems reduce energy use. Over half of the building's energy now comes from photovoltaic arrays in a neighbouring field, which partially power two other buildings on the campus. By offsetting the already low energy consumption, which is just 11% of an equivalent structure, the building is expected to be operationally carbon neutral. Water is precious in Arizona. This building links to the new grey water main of the main campus. It allows for the re-use of non-potable water and incorporates measures such as low-flow fixtures. The results are impressive: 90% total potable water reduction in a desert climate.

To reduce the energy needs of the laboratories, Arup specified variable controls on their equipment, and an active evaporative cooling system with shortened ductwork, which reduces overall pressure drops. Occupying a third-floor penthouse the laboratories are also sealed off from the lower floors, making them as secure and as energy efficient as it is possible for laboratories to be.

Arup and the design team brought to Flagstaff knowledge and techniques developed on projects in very different physical and intellectual environments and locations. This award-winning building is proof that creativity and the willingness to innovate can be harnessed to great effect almost anywhere ■

Project
Qingdao EcoBlock
Location
Qingdao, China
Client
University of California Berkeley

Green living

For the next 20 years, up to 10m people a year will move from China's countryside to urban areas. This unprecedented migration is placing huge demands on the nation's cities, resources and environment and is contributing in no small way to global climate change. Students at University of California Berkeley, led by Professor Harrison Fraker, conceived a new model for sustainable community development. It has the potential to reduce the environmental impacts of large-scale residential development by 40%. They called upon Arup to provide technical collaboration on their 'EcoBlock' project, which develops a realistic option in terms of meeting growth demands while limiting the environmental impact.

China's traditional approach to housing the massive influx of people to its urban areas is to build 'SuperBlocks'. These often gated communities are on a mammoth scale – typically over one kilometre square. They tend to create social segregation, encourage car use and place enormous demand on centralised infrastructure such as electric power lines, sewage treatment plants, sewers and sanitary water supply. Eleven million housing units per year are built in China, the equivalent of up to 15 SuperBlocks every day. While no doubt efficient at accommodating large numbers of people, SuperBlocks create a demand for new infrastructure that is difficult to meet, leading to significant environmental problems.

The Arup and UC Berkeley collaboration – dubbed the EcoBlock – is designed to replace SuperBlock developments. The EcoBlock will be largely self-sufficient in terms of energy and water use, which has the potential to massively reduce the pressures on centralised infrastructure. It can meet all of its energy needs from on-site renewable energy sources and can reuse 100% of its wastewater and rainwater in order to meet 85% of the block's demand for water. As a result, the net carbon emissions associated with the EcoBlock's energy use will be zero.

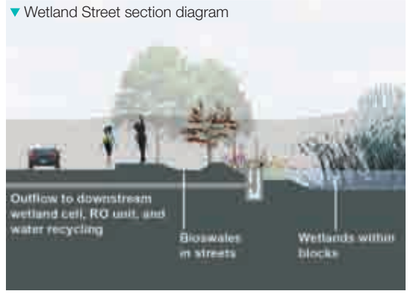
The EcoBlock works by harnessing resources that are traditionally wasted and transforming them into valuable assets. The sun's rays, wind, sewage sludge, food waste and garden waste are converted into energy to power residents' homes. Rainwater and wastewater are cleaned and used for drinking, showering and cooking. Crucially, the EcoBlock is designed to be mass replicated. This has the potential to result in huge reductions in carbon emissions, water pollution and waste generation and reduced demand for centralised infrastructure.

Arup used its expertise in sustainable design around the world to build on the UC Berkeley students' concepts and evolve them into technically feasible system designs. Importantly, Arup demonstrated that these objectives can be achieved using proven technologies that are readily available from Chinese manufacturers and suppliers. Energy demand will be met by three on-site renewable energy sources: photovoltaic panels; wind turbines integrated into the buildings; and an anaerobic digester that will transform the EcoBlock's organic waste into biogas for heating and electricity generation. Bio-swales and constructed wetlands collect and clean wastewater while also providing green spaces for residents, and generating additional garden waste for biogas energy generation. The EcoBlock is unique in integrating all these separate systems into one project, suitable for large-scale use.

The EcoBlock will be constructed using methods and materials that reduce demand on natural resources, such as cement with high fly-ash content – a waste product from burning coal. When taken to the next stage, seismic performance of the design will be considered. The layout of the EcoBlock counters the social segregation created by large-scale SuperBlocks, while acknowledging the desire for a clear identity within the Chinese culture. Main streets through the neighbourhood are left open to the public, while a series of smaller communities are set around semi-private courtyards and gardens in the middle of the blocks. Research has shown that the scales proposed are ideal for a neighbourhood feel, promoting a sense of community.

After a series of meetings with the local government, a site for construction of the first EcoBlock has been selected in the coastal town of Qingdao in Eastern China, known for its beer and sailing. Significantly, it has been identified for 'demonstration project' status by the Chinese government. The potential importance of the EcoBlock has been recognized internationally. Funding for the detailed design stage of the project is being provided by the Paul Allen and Family Foundation, the Gordon and Betty Moore Foundation, the Energy Foundation and the City of Qingdao Government ■

▼ Wetland Street section diagram



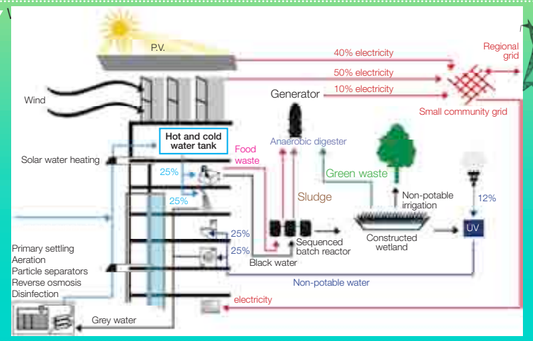
▼ Low-carbon solutions

EcoBlock objectives

The key objectives of the project were to design a new model for sustainable urban neighbourhoods. They are:

- Easily replicable and scalable
- Economically viable
- Based upon proven technologies that are readily available in China
- Self-sufficient with regard to water, waste and energy resources
- Recycling 100% wastewater on site
- Significantly reducing potable water demand (as close to 100% reduction as possible)
- Generating 100% on-site renewable energy
- Designed to encourage journeys by foot, bicycle and transit
- Designed to provide 40% to 60% of the site area as green space

▼



Project
Bay Meadows Phase II
Location
San Mateo, California, USA
Client
Bay Meadows Land Company

Giving back to the city

Sometimes a development's positive effect on a community is much greater than the sum of its parts. Bay Meadows, on which Arup is civil engineer and sustainability consultant, is one such development. This carefully planned neighbourhood admirably champions the City of San Mateo's need to accommodate its projected population and employment growth, while improving the city's street grid. It adds connections to transit and gives city residents over 15 acres of parkland and greenways – twice that required under law. Arup's stormwater management scheme provides a creative and sophisticated solution to water capture, storage and recycling in Bay Meadows itself – and also solves nuisance flooding in neighbouring areas.

▸ San Mateo, like many Californian communities, is working to assist the accommodation of California's projected 30% increase in population by 2030. The 83-acre Bay Meadows racetrack site is a significant step towards broadening the employment base and housing supply, critical to supporting this population growth. Designed to respect and integrate with the City's strong neighbourhood tradition, Bay Meadows will enhance community life for all San Mateo residents, not just those who will be fortunate enough to live there.

Like much of the Bay area, Bay Meadows comprises low-lying land. Residents of nearby Saratoga Drive and the McCelland neighbourhood have suffered chronic flooding and waterlogged roads for decades. Thanks to comprehensive stormwater measures, these events are likely to be consigned to history. Arup's water and flood management strategy is central to the success of the entire scheme, with many new features doubling up to alleviate flood risk and manage stormwater. An attractive pond, for example, also keeps and cleans stormwater, as well as providing 600,000 gallons of year-round water storage, which is vital to the city's ability to fight fires. It also avoids the need to construct a separate water storage facility.

A masterstroke in the Bay Meadows plan is the provision of floodable recreation fields, designed to accept and shed detained water, during and shortly after major storms, without compromising the playing surfaces. Indeed, sports enthusiasts could be forgiven for thinking that the development was created solely with them in mind: a floodwater retention facility is sized to be cleverly disguised as a baseball or soccer pitch.

With so much underground parking required to maximise the efficient use of space, Arup devised a sophisticated stormwater treatment scheme, complete with kerbside bioswales and rain gardens. These allow street runoff to be filtered and to soak away – or run into – an underground drainage system. The system has many virtues: it is easy to maintain, safe for the public, and even contributes to mosquito control.

The positive effects of the Bay Meadows development are not confined to water, however. Seen from the air, the negative impact on the city of 83 acres of enclosed horse racetrack is laid bare. It forces car traffic to travel around its perimeter, taxing the city's road network and acting as a barrier to pedestrians, cyclists and bus transit alike. With its urban-scale street grid, the development will unify

◂ **Kerbside water treatment**
Runoff from the street passes through the planters and is filtered by the soil and vegetation before either soaking away into the ground, or, where precluded by underground parking, being collected by an underground drainage system. Public safety, mosquito control and ease of maintenance all drove the design to attain a superb blend of priorities within one public amenity. Bioswales and raingardens also play their part in a comprehensive suit of best management practices.

the southern neighbourhoods of San Mateo. It slots into the existing city fabric, extends the existing street network, and eases congestion by providing two new railway crossings. The relocated Hillsdale Caltrain Station will bring Bay Meadows residents to within a 15-minute walk of a transport hub, while offering San Mateo's residents greater opportunity to abandon their cars and embrace a more sustainable lifestyle.

Residents' leisure options will also expand considerably. Bay Meadows provides 15 acres of parkland spread over three city parks – nearly double that required by the city code. And San Mateo needs parks. Of these, two 1.5-acre neighbourhood parks will become local gathering places, with facilities such as children's play areas. But the jewel in the crown of the development is a 12-acre community park with the potential for a variety of uses. These range from passive formal spaces, native drought resistant plantings around a new pond, to much-needed sports fields.

The development is conceived to bring better use of a large track of land interrupting the City of San Mateo's fabric, achieved with the long-term obligations to the next generation of residents, and realised with sustainable outcomes at the fore. Bay Meadows Phase II will deliver a diverse housing mix, office space to accommodate new businesses, local shops, pedestrian and bicycle access, ample public space, and enhanced infrastructure. All this is within an easy walk of a major transit service to San Francisco to the north and Silicon Valley to the south. Guided by the confidence of the developers, Wilson Meany Sullivan, created within the collaborative spirit of the planners, Cooper, Robertson & Partners, and shepherded through the entitlements process by the City of San Mateo, Bay Meadows Phase II will stand the test of hindsight in the years to come as a well planned, 21st century community ■

Project
Dubai Waterfront
Location
Dubai
Client
Nakheel

Solar troughs ▶

New city on the coast of southern Dubai called Waterfront ▶

Guiding the waterfront

Nakheel, the largest developer in Dubai, has begun constructing its most ambitious project yet – a new city on the coast of southern Dubai called Waterfront. They aim to transform 120km² of desert between Jebel Ali Port and the Dubai-Abu Dhabi border into a low-carbon city for 1.5m people. Nakheel has proposed ambitious sustainability targets based on international best practice. The challenge for the Arup team is to help implement these objectives into urban form on an unprecedented scale – and in an extreme desert climate.

Mixed use and compact district ▶

▶ Over the next 14 years, Dubai Waterfront will grow to house over 1.5m people. A series of targets have been set by the developer that, if achieved, will result in the creation of the largest low-carbon city yet developed. Nakheel turned to Arup to prepare an energy strategy for the Waterfront, to meet its ambitious goals.

Dubai has an extreme environment, where summer temperatures of 50°C are common. Air conditioning represents up to 60% of the energy demand of buildings. Almost all transport is by private car. The Arup team knew from the outset that a low-carbon city designed for these conditions would need a dramatically different approach.

The energy strategy covered all aspects of a city's operation – buildings, transport and infrastructure. Arup proposed sourcing as much energy as possible from renewable means; substantially reducing energy consumption; delivering efficient energy to Waterfront through a series of on-site power stations; and sourcing as much energy as possible from renewable means – such as the sun and wind, via solar 'troughs' and wind turbines. As it developed, the Arup team realised that each aspect of the project was interdependent. To achieve the desired results the project needed a comprehensive set of urban design guidelines to sit alongside the energy strategy, for all the Waterfront contractors to follow.

For example, Arup's energy strategy suggests that in order to reduce reliance on cars, every home should be within 300m of public transport. This seems a simple enough objective. However, for much of the year it is simply too hot to walk outside, so the original plans – for separate apartment blocks set within their own grounds – would actively discourage use of public transport. Arup's urban design guidelines that accompany the energy strategy suggest linking dense mixed-use areas to public transport via climate-controlled environments, such as covered walkways and tunnels. In this way, people would be encouraged to change their behaviour and decrease their dependence on cars. This particular strategy also provides Nakheel with valuable real estate opportunities, as any businesses situated within these climate-controlled passages would experience high levels of footfall.

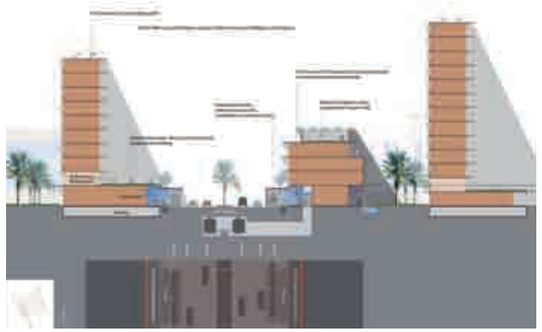
Another crucial element of the city's energy strategy is the creation of urban microclimates, favourable for walking. Designing buildings that are closer together creates shade and blocks hot desert winds. This scheme – along with creating a series of urban centres with offices, retail outlets, schools, healthcare and community centres – would encourage more people to walk which would further reduce car dependency.

Approaching the development in this holistic way will make the city's targets achievable – even though the proposal itself is far from straightforward, as one third of the site has already been planned.

The proposed strategy required Arup and Nakheel to rethink the existing plans for the remaining two thirds of the site. It also requires a change in the way real estate developers work.

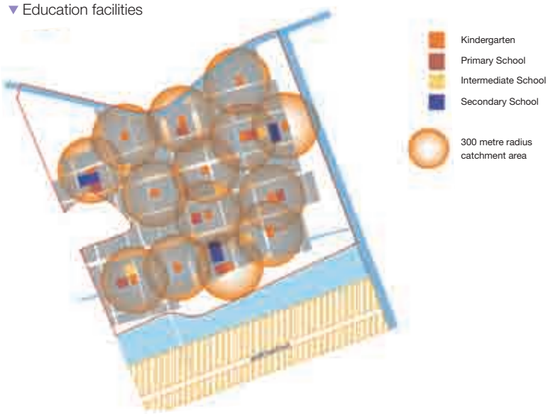
Nakheel will need to take on the construction of power stations and public transport infrastructure, which will then be operated by private-sector bidders. Nakheel is forward-thinking. Arup will continue to work closely with the Waterfront project team over the coming months to implement the strategy recommendations, while taking into account the construction programme and commercial constraints. The result is likely to be a fitting example to the rest of the world, and may result in the creation of a city whose urban form will meet the challenges of the next 100 years ■

▼ Primary streets

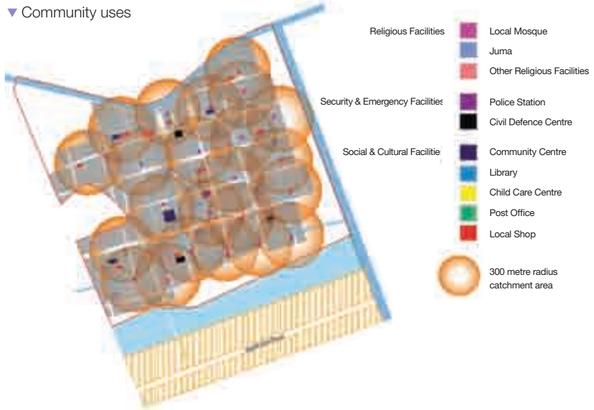


▼ Secondary streets

▼ Education facilities



▼ Community uses



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Project
Sippy Downs
Carbon Accounting
Location
Queensland, Australia
Client
Investa Property Group

Carbon audit

Change is afoot in Australia's construction industry, with more and more companies recognising the impact their activities have on the environment. Arup is working with progressive property developer Investa Property Group to undertake the first carbon audit for a residential development. The hope is that this type of benchmarking will become an industry standard.

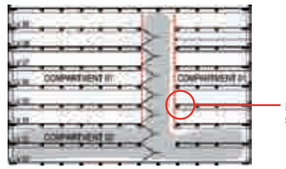
▸ As part of the development of Bellflower Sippy Downs, Investa funded an AUS$3m rehabilitation project to reinstate the path of the dilapidated Sippy Creek. The project involved the rejuvenation of 21ha of former grazing land within the site, plus the introduction 300,000 individual plants from 130 different native species to the banks of the creek. The developer recognised the opportunity to match its commercial realities with a desire to enhance the local ecosystem by demonstrating that any carbon created through their construction activities would be offset by the renewed green habitat.

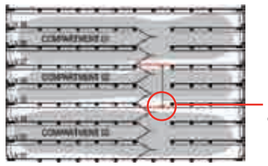
Given the size and scope of the project, Investa turned to Arup for the unusual task of investigating the project's carbon balance. The process involved comparing the amount of carbon taken out of the atmosphere – sequestered – by the revived Sippy Creek green corridor, against the carbon emissions created by the development itself.

To determine the CO_2 output of the project, Arup collected detailed information about the project, including equipment used during construction, the type of work undertaken and the site working hours. They also calculated emissions from the disturbance of soil in the Bellflower development, which were found to be surprisingly high. Using carbon-modelling software, the Arup team then estimated the carbon sequestration from the revived Sippy Creek.

The results showed that the rehabilitation of the Creek more than offset the carbon emissions associated with Investa's construction of roads and services – not including embodied energy – for the site. Furthermore, by estimating the average emissions attributable to the construction of homes on the estate at 12 tonnes per plot, Arup conservatively estimated that within 30 years the entire carbon output of the project would be sequestered. With the new trees likely to remove carbon dioxide for at least a further 70 years after this, the landscaping program was deemed a great success ■

Project
Stockland Head Office
Location
Sydney, Australia
Client
Stockland





Smoke screen

Australian property developer Stockland had lofty ambitions for its new headquarters: to increase interaction between its different business units, create a more open working environment and reflect the firm's strong green credentials. Their choice to refurbish eight storeys within an existing 32-floor high-rise tower made this more of a challenge. However, project engineers Arup used pioneering fire engineering to demonstrate that existing buildings can be rejuvenated, while achieving environmental excellence.

▸ The design solution proposed by the project's architects, BVN, was to connect the floors with an open atrium and central staircase. Arup environmental consultants developed the design to increase fresh airflow by 200% and enhance natural light throughout the tenancy. However, both the architectural vision and the environmental objectives required the atrium to be as open as possible – an aim that contravened the Building Code of Australia (BCA) fire codes.

The spread of fire and smoke is a major concern for open atria and interconnected floors, so BCA codes specify that only two storeys may be linked together. The design team realised that to achieve their vision, rather than following the prescriptive BCA code they would have to take the alternative performance-based approach to fire safety. This allowed them to be more creative with their design, but placed the onus on the engineers to achieve a fire-safety solution that satisfied the New South Wales Fire Brigade.

The most commonly used solution of installing smoke exhaust to draw smoke away from floors in the case of a fire was not an option, as the necessary exhaust shafts could not be installed through the floors above, which were leased to other tenants. Another possibility was the use of vertical fire curtains that would drop in the event of a fire, to separate each floor from the atrium. While this was technically feasible, the huge area of curtains needed would have made it very costly and time consuming to maintain and test.

Arup identified a solution that had never been used in Australia before: a horizontal fire curtain. This flexible fire-resistant fabric is carried horizontally on thin wires, similar to a swimming pool cover. It closes voids and stops the spread of fire and smoke. Arup realised that careful placement of just two horizontal curtains at floors 25 and 27 – along with small vertical curtains to seal off the stairs on the same levels – would split the office into three compartments in the event of fire; two of three storeys and one of two storeys.

Before advocating the use of such a new technology, the Arup team made use of its internal skills network – the firm has over 150 fire engineers worldwide – to review the performance of fire curtains. This gave them the confidence to recommend the solution. After extensive work to reassure Stockland and the fire and building authorities that the innovative solution was sound, the team got the go ahead for the first-ever use of horizontal fire curtains in Australia.

Stockland has experienced significant increases in the productivity of its staff, as well as benefits to its business through enhanced communication, due to the new layout. The architectural vision has been met, and an ageing office building has been rejuvenated into a vibrant new space. None of this could have been achieved without the fire engineering design that enabled the open atrium design to be embraced. This award-winning project showcases what can be done with existing building stock, both in creating an exciting new work environment, and in achieving excellence in environmental performance ■

Project
The Pinnacle – Advanced Structural Fire Analysis
Location
London, UK
Client
Arab Investments Ltd

▲ Vertical deflection of the structure following exposure to a design fire.

Tower of **strength**

The Pinnacle will be one of London's tallest skyscrapers. The building's complex shape and geometry meant that Arup's structural fire engineers needed to create new models for advanced structural fire analysis to predict how the building would behave in a severe situation.

▶ Heat water to its boiling point and it will vaporise into steam. Heat a building and its behaviour is less predictable. When the 62-storey office building known as the 'The Pinnacle' is built in the densely-developed City of London, it will be one of London's tallest skyscrapers. Its scale and unusual architecture pose complex questions about how the building will behave in the case of fire. The challenge for Arup's fire engineers was to answer them.

Any high-rise building needs active fire safety systems for early warning and evacuation, including good stairwells and sprinklers. These systems focus on occupant life safety rather than structural performance in a severe fire. In what is an intellectually challenging and abstract engineering discipline, Arup's structural fire engineers deal with the 'worst case' scenario. They identify how a structure would perform once fire has taken hold, examining its overall stability and the integrity of its structural elements. For a signature building such as The Pinnacle, in an international financial centre such as London, this is a key consideration of the building's risk profile.

Arup's structural engineers came up with the structural concept first of all. Then the fire engineers worked from first principles to predict how the fire would affect that structure – how heat would cause the structural arrangement to change shape, weaken and therefore influence its overall stability. The heating of the elements imposes forces and strains in the structure, due to its changing in shape with increasing temperatures. These would not normally be considered and designed for under ambient temperature conditions, nor under traditional Building Code based fire protection strategies. Such analysis becomes more challenging as the complexity of a structure's configuration and geometry increases. The 62-storey Pinnacle, with its complex form and geometry, has pushed the boundaries of structural fire analysis as well as those of design.

Historically, engineers have turned to published tables in Building Codes to calculate resistance to fire. This is true of all countries around the world. The tables state fire resistance of a building of a certain height in terms of minutes. The underlying methodology is to measure how long a component part such as a beam lasts before it fails when subjected to steadily increasing heat in a furnace. The findings are 'scaled up' to provide a fire resistance value for a building, and therein lies the problem. It is impossible to scale up accurately when dealing with a complex structure such as that forming the Pinnacle.

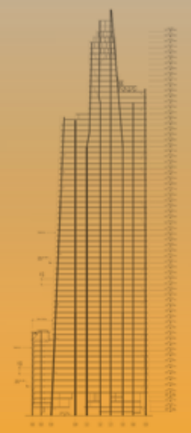
Recent strides in understanding how fire spreads and how materials and structures behave when heated inform Arup's approach, allowing its structural fire engineers to quantify the real performance of the building's structure in a severe fire. The severe fire represents a reasonable worst-case scenario, and is agreed in advance with the approving authorities. The analysis quantifies in which fire resistance is over-specified, allowing the structural design to be made more efficient and less costly in places.

Such techniques also allow the structural fire engineers to pinpoint under-specification – the design's most vulnerable aspects – so that Arup's structural engineers can then strengthen the main structural design. For the Pinnacle, the initial analysis revealed high strains in the concrete slab over certain floor beams, which in turn prompted additional reinforcement measures to be included in the design.

It is Arup's ability to quantify measures such as load-bearing capacity in the event of a fire that is so special. Advanced structural fire analysis gives meaningful outputs, which engineers can use to optimise a building's design. In essence, it allows the targeting of higher resistance materials and design techniques for key load-bearing elements of the building in the event of fire.

Clients want certainty as to what would happen in certain scenarios so they can spend their safety budget wisely. Arup's experts provide just this ■

An expert for every scenario



The challenges of designing an exceptionally tall building are not confined to structural fire analysis.

The higher the building, the heavier the load it must carry. Arup's geotechnical engineers specified some of the deepest pilings in London to support the Pinnacle. At 50m deep and 2.4m in diameter, they go right through the London clay all the way to the underlying strata of Thanet sand.

The effect of wind on a tall building is acute, and Arup's wind experts were an integral part of the team.

The Pinnacle, with its innovative glazing system has operable windows in a complex façade, in order to minimise energy-hungry air conditioning – unheard of in a building of this type, and making the effect of the wind harder to predict.

Under the City of London's acoustics requirements, the building must be quieter than streets it stands on, and not contribute to higher noise levels in the city. The Pinnacle's operable windows can let in street noise too – perhaps more than its occupants might like – so Arup's acousticians had to consider noise levels from both perspectives and come up with technical solutions that satisfied both occupants and legal requirements.

Arup's wider team included security experts, a disabled access consultant to ensure the building is compliant with legal requirements and even an expert on TV interference. Its height means that any effect on the TV signals received by neighbouring buildings must be checked and anticipated too.

Project
High Speed 1
Location
London via Stratford, Ebbsfleet and Ashford International stations to the Channel Tunnel entrance, UK
Client
London & Continental Railways

Arup's largest project
Arup has been involved with High Speed 1 for over 20 years. Some 1,600 Arup people have contributed a collective 1,300 man years designing and project managing. The 109km-long railway project involved 50 kms of large diameter tunnelling under 2,600 properties and 150 bridges. It facilitated Europe's largest environmental programme, including the planting of 1.2m trees, archaeological investigations, revealing a Roman town with seven temples and a 400,000 year old giant elephant skeleton along the way.

The **big** picture

Infrastructure is the essential framework on which the social and economic success of a country is built. As the Victorians recognised, a railway signifies far more than the sum of its physical parts. It is a means to create wealth, improve lives and give a nation the promise of universal mobility. High Speed 1, as the Channel Tunnel Rail Link is now known, has proved to be a powerful catalyst for the regeneration of swathes of the UK's south east. It has given the UK its first high-speed link with continental Europe. As a project, it represents a highpoint in the UK's strategic infrastructure planning.

▶ When the idea of a high-speed international rail link was first mooted in the late 1970s, railways had long since fallen from grace. The focus of the UK government at that time was roads and highways, and the private car was king. With little apparent consideration for future needs, the UK's first-ever international railway was initially envisaged as a minimum specification railway, tunnelled under south London and terminating under King's Cross station. Threatening 5,000 homes with noise and intrusion, it was a proposal based on transport considerations alone.

A small group of Arup engineers, planners and economists were dismayed at the missed opportunity for the UK. On their own initiative, they devised an alternative route through Stratford and Ebbsfleet/Gravesend – economically deprived areas that would benefit from regeneration. Their plans considered not just international travel, but also regional commuter and freight trains. This small group convinced Arup's board to become 'the client' for a while. Arup funded the development and promotion of the speculative proposal for an alternative route, risking significant disapproval from the status quo. Against the odds, the alternative route found favour, was championed by successive senior politicians, and the rest, as they say, is history.

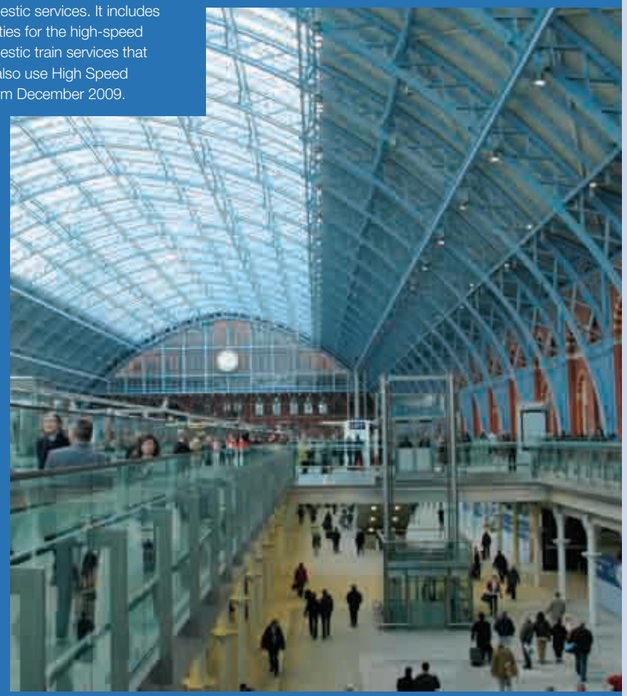
When High Speed 1 was opened by The Queen on 6 November 2007 – on time and within budget – it heralded a new era in rail travel for the UK. And as a major piece of enabling infrastructure, it proved key to London winning its bid to host the 2012 Olympics. Furthermore, it will facilitate the regeneration of deprived areas in the country's south east.

Putting a value on High Speed 1 is an almost impossible task. While the total project cost was £5.8bn, conservative estimates confirm that the project has directly leveraged around £10bn in investment in regeneration. However, the further long-term positive effects can only be guessed at. The challenge in a densely populated country such as the UK, with its pockets of deprivation, is to provide infrastructure that can create a focal point for businesses, helping to attract workers and investment that such an area needs for regeneration.

The four main objectives of High Speed 1 were to provide an international railway; deliver a high-speed commuter line; introduce modern railway technology to the UK; and assist in the regeneration of Ashford, Ebbsfleet Valley, Stratford and King's Cross. Mission accomplished. Freight will be further enhanced by the displacement of passenger trains from the existing 'classic' railways, thereby relieving pressures on the UK's increasingly congested roads, and realising the potential of the Thameslink core station at St Pancras International. ▶

One building, three centuries of British design

Considered one of the world's most beautiful stations, the Victorian-built St Pancras station has been refurbished and extended to become the UK's new international rail terminus. It accommodates Eurostar and cross-London Thameslink services as well as the Midland Mainline domestic services. It includes facilities for the high-speed domestic train services that will also use High Speed 1 from December 2009.



▶ The monumental construction challenges of the railway are well known: 50km of tunnels and a new bridge over the River Medway – one of 150 new bridges. But the greatest challenge for Arup, as part of the Rail Link Engineering consortium, was in creating the myriad interfaces with the existing railway.

Each of the UK's classic railway lines has its own history, having been developed initially under private ownership according to regional need. Until the mid-20th century there was no national ownership or leadership. The legacy of such fragmented beginnings is a significant regional variation between networks: the tracks may be the same size, but other aspects of the railway such as signalling systems and power, are very different. Each interface has to be resolved locally. The experiences of High Speed 1 have had a positive effect in helping to accelerate the standardisation of technology and processes that Network Rail is now pushing through.

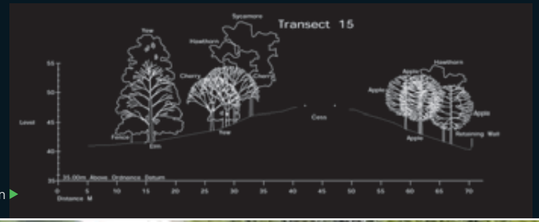
Looking to the future, the Trans-European Network – which will connect the major cities of Europe – is being designed and constructed for 'interoperability', or uniform standards. High Speed 1 conforms to these standards.

To call High Speed 1 simply a 'rail project' is to understate its significance to the UK, both today and in the future. It will challenge governments with tantalising new possibilities. Its designers have incorporated functionality which, though unused at the moment, makes a future link possible between St Pancras International and the UK's two main arteries – the East Coast and West Coast Mainline railway. Such a 'joined-up' railway system would be a glittering prize indeed for a government with the courage and resources to enact such a vision.

Like their Victorian master engineer forerunners, the designers of High Speed 1 have created both a solution to today's pressing needs, and an opportunity for wealth creation that may significantly benefit future generations ■

Project
Engineering a 21st Century Railway
Location
Southern England, UK
Client
Network Rail LNET, Network Rail SET, Edmund Nuttall Ltd

Embankment in cross section ▶



Back on track

Uncomfortable train journeys for commuters and costly speed restrictions for train operators on the UK's railways are most pronounced in a hot dry summer. Over decades, trackside vegetation has worsened the movement of the clay under hundreds of miles of railway lines in the UK's south east. The answer lies in 'vegetation engineering' – an innovative and strategic approach to track management, at which Arup is at the forefront.

▶ Those who travel by train across southern England are likely to have experienced the bumpy ride that results from the stressed rails that result from shrinking and swelling clay embankments.

Much of the UK's Victorian-era railway and embankment infrastructure is built on plastic clay, which is particularly vulnerable to swelling and shrinkage. The embankment system is complex to analyse: the Victorians would often re-use soil excavated from one area to build up an embankment further along the line, without ensuring that it was properly compacted. Over decades, gradual movements in the clay have affected the infrastructure, causing uncomfortable journeys for travellers and expensive speed restrictions for train operators. Only recently, the extent to which such movement is closely related to vegetation has become apparent.

Oak, ash and willow trees are the main culprits, because of their long root systems for extracting water from the soil. Being deciduous, their demand for water is seasonal, which worsens their effect on clay.

The shrinkage and swelling of clay tends not to be uniform, and so is difficult to predict over a lengthy track. Wetter winters and hotter summers have exacerbated the problem, which has been building up over decades. The effects of climate change are likely to worsen it further in the future.

Historically, track owners have been geared to clearing vegetation that may compromise safety - such as trees that could topple onto the line, or simply drop their leaves onto the line - rather than managing vegetation as part of their asset-management strategy. Arup has devised best-practice guidance and a vegetation-management strategy for track owners. It provides for embankments to be re-engineered and landscaped over time. The aim is for offending trees to be removed and replaced with other indigenous plants. This will encourage biodiversity in the trackside habitat corridors, without compromising the engineering performance of the tracks. The transformation will happen at a pace that will not shock the system.

In tandem with its work on geophysical and vegetation engineering for the industry, Arup is monitoring water pressure in two specific locations, Pound Green and Magnolia Road, in London. The two projects allow Arup to study the effect in-depth of nearby trees, and to obtain high-resolution data without the need to work on a live railway. The findings provide 'micro' scale data on the behaviour of different soil types and tree combinations. This will enhance the management of clay embankments that are subject to seasonal movements in the UK's railways ■

top right image © Plowman Craven Associates

Project
Information and Communications Technology (ICT) for Ebbsfleet Valley
Location
Ebbsfleet Valley, Thames Gateway, UK
Client
Land Securities

High-speed innovation

Ebbsfleet Valley is major development at the heart of the Thames Gateway initiative, the largest urban regeneration scheme in north-west Europe. The initiative is creating opportunities for a large number of exemplar projects – many involving Arup. Ebbsfleet Valley's groundbreaking communications programme, for example, will provide 10,000 new homes with high-speed optical fibre broadband technology, helping the UK to compete with leading next-generation networks around the world.

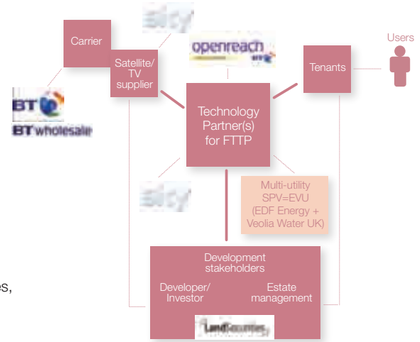
▶ In the UK, the vast majority of homes are still connected to telecommunications networks by copper cables. While relatively quick home broadband speeds can be achieved, this type of communications infrastructure is constrained by distance. It is generally not up to the task of delivering the kinds of high-speed network services that are standard across much of the Far East and mainland Europe. Land Securities, a UK-based property developer, was looking to change this. They wanted IT excellence to distinguish the Ebbsfleet Valley – and saw significant value in the new community having a high-quality broadband infrastructure.

Land Securities decided to take the bold step of pioneering cutting-edge optical fibre technology at Ebbsfleet Valley, and Arup advised it on how this could be delivered, both technically and commercially. As well as delivering high-speed data and entertainment services to residents and businesses, Land Securities realised that high-speed 'fibre to the premises' (FTTP) technology could also support estate management services.

These might include up-to-the-second transport and traffic information, intelligent signage for parking spaces, and CCTV security systems.

The technology could also play a role in encouraging people to behave in a more sustainable way. For example, residents might be encouraged to use buses instead of cars, with the delivery of real-time public transport information on mobile phones and into people's homes. Land Securities also wanted to eliminate some of the less desirable side effects of traditional communications networks, such as junction boxes in the streets and satellite dishes on houses.

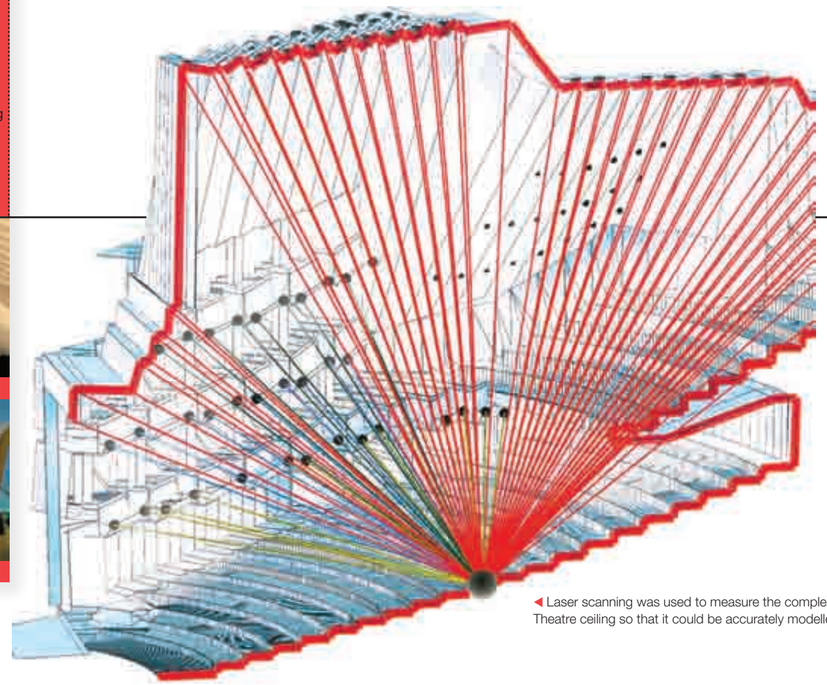
The high-speed optical fibre network being deployed at Ebbsfleet Valley is significantly lower in cost than traditional copper telecommunications infrastructure. Arup's approach for developing a partner-based solution was a key element in making FTTP a reality. The four elements critical to the project – estate management, residents, community, commerce – were all embraced by the Arup team ■



Structure diagram

The Ebbsfleet Valley FTTP network is led by British Telecom's Openreach division with product and procurement support from BT Wholesale. Sky is providing BT Openreach with the Fibre IRS (integrated reception of satellite and terrestrial) technology, which allows customers to receive satellite and freeview signals at remote locations, in this case via a BT exchange. The infrastructure for the network has been installed by Ebbsfleet Valley Utilities – a joint venture between EDF energy and Veolia Water UK. Arup provided the project with programme management, information and communications technology consultancy; and civil engineering expertise.

Project
Building Information Modelling at the Sydney Opera House
Location
Sydney, Australia
Client
Sydney Opera House



◀ Laser scanning was used to measure the complex Opera Theatre ceiling so that it could be accurately modelled in 3-D.

The names Utzøn and Arup are inextricably linked with the Sydney Opera House. Together, they created what is without doubt the world's most iconic performing arts centre. Thirty five years since the opening of this elegant and daring building, the architectural and engineering firms behind it are once again applying the very latest technology to help address the challenges this unique venue will face in the 21st century. This time the virtual tool, Building Information Modelling (BIM), is providing a new platform for assessing renovation proposals, while creating a database that will serve the Sydney Opera House well into the future.

An icon revisited

▶ The Sydney Opera House symbolises Australia's achievements and ambitions. It is a deserving recipient of UNESCO World Heritage status. But it refuses to rest on its glistening laurels. One of the most heavily used performing arts centres in the world, it hosts over 2500 performances and events each year. To deliver this audacious schedule, it relies upon systems and equipment that are as complex as the intricate enveloping structure. The soaring shells cover no fewer than seven performance spaces, served by 46 rooms that house building services, 17 lifts and more than 1,500 additional rooms. In order to keep the 35-year-old venue running smoothly, facility management spans everything from day-to-day operation and maintenance of the building through to major renovations.

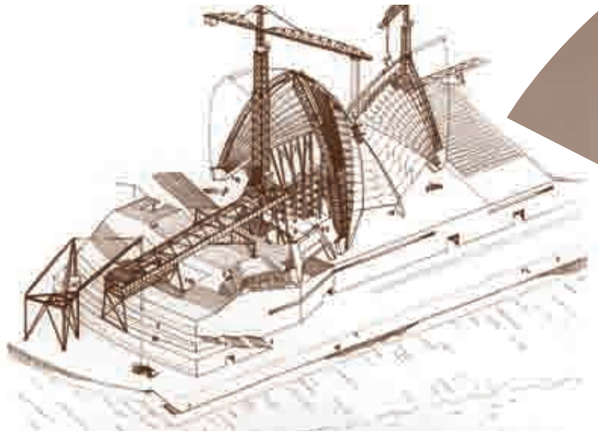
Ove Arup's transformative Sydney Opera House commission began in the 1950s, working as design engineer alongside visionary Danish architect Jorn Utzøn. Arup made Utzøn's fabulously daring design buildable, with ground-breaking use of computers to model the roof and analyse its structure. Back then, 3-D analysis that would take just minutes on today's desktop computers took 12-14 hours on computers that filled entire rooms.

Since the opening of the Opera House in 1973, Arup has had an ongoing involvement with the building, recently reuniting with Utzøn's architectural practice, and Sydney architect JPW, for design work on a program of refurbishments and upgrades. At the outset, the design team recommended the creation of a detailed 3-D model of the facility in order to trial design ideas virtually.

For a facility as large and complex as the Sydney Opera House this was a major undertaking. The Arup team had the advantage of being able to revisit the vast number of original plans developed in the firm's early days. The process combined Arup's rich heritage with state-of-the-art virtual modelling skills. Conventional site inspections and surveys were undertaken, alongside modern laser scans. Conflict-detection software was used to reconcile any discrepancies. Work on the detailed 3-D model is still ongoing, incorporating new areas as funding for upgrade projects becomes available. ▶

The judges described the project as “an exemplar that clearly demonstrates the application of an integrated digital solution as a world class facilities management tool.”

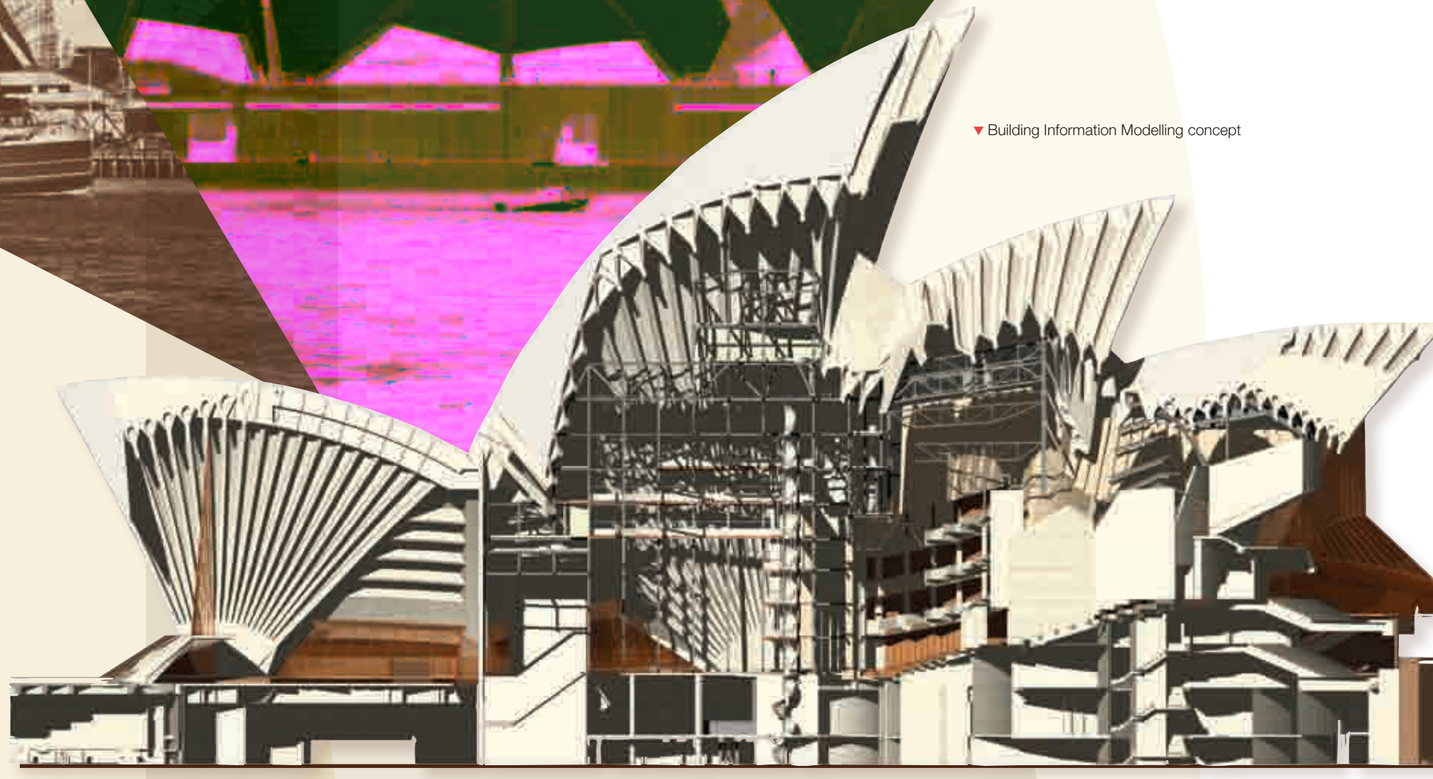
▼ Sketch of construction methodology



Sydney Opera House in construction ▶

◀ Sydney Opera House - present day

▼ Building Information Modelling concept



▶ The 3-D model invited extension into BIM – where computer images can be linked to analysis tools – to support the design of the on-going and proposed refurbishments and renovations. Arup took the lead and explored the creation of links between the new 3-D model and a range of software packages to perform structural, acoustic, and fire engineering analyses. Once again Arup was pushing the boundaries of technology to address the design challenges of the Sydney Opera House.

Arup used experience gained in creating similar links for the Beijing National Aquatics Center, dubbed the Water Cube, constructed for this year’s Olympics. These links allowed information contained in the 3-D model to be shared with the specialised analysis models. This minimised the duplication of data creation and so speeded up the iterative analyses, with the end result that optimum design solutions could be found more quickly. Applied in reverse, the process allowed the results of the specialised analyses to be accepted directly into the 3-D model, updating it with the latest design results.

With the development of the 3-D model of the Sydney Opera House now well underway, users have begun to notice other aspects of BIM that could be incorporated over time to support operations at the House. One such opportunity might be visualising the sequencing of works in areas featuring complex arrangements of plant and structure, and so assisting works contractors with their own programming. It could also be used to capture and incorporate ‘as built’ information about the work undertaken as each contract is completed.

Another opportunity would be to develop the 3-D model as a two-way graphical interface for monitoring and managing aspects of the building services, and the fixtures and fittings. To help demonstrate this opportunity, Arup has created a trial programming links from the 3-D model to some existing facilities management schedules. For the user, the links would function in either direction – for example, from the room selected in the model to the information about the room, or vice versa.

Developing such links, and other ways of making the model more ‘intelligent’, were the subject of a recent government-assisted research project. The Facilities Management Association of Australia subsequently recognised the Sydney Opera House’s work with BIM by featuring it in publications as an ‘exemplar’ for the industry.

Late in 2007, the work was also recognised by the Association of Consulting Engineers of Australia (ACEA), one of Australia’s most prestigious engineering award ceremonies. In their annual Awards for Excellence, ACEA awarded Arup and the Australian Cooperative Research Centre for Construction Innovation its *Project of the Year Award*, with Sydney Opera House as their client. The judges described the project as “an exemplar that clearly demonstrates the application of an integrated digital solution as a world class facilities management tool.”

BIM represents the world’s best practice in the design, construction, and operation of building projects; Arup’s design engineers are pushing the software to a new level. Perhaps their greatest reward, however, is in reconnecting with the Sydney Opera House – once again bringing new technology to this iconic venue and in doing so, helping to secure its future as one of the world’s most exciting performing arts venues ■

Project
Sedibeng (Sharpeville) Regeneration
Location
South Africa
Client
Sedibeng City Authority

Remembering the past, **celebrating the future**

Sharpeville is a potent symbol of the human rights movement for the new South Africa. The infamous massacre of 1960 – in which police fired into an assembled crowd of protestors, killing 69 and wounding 178 – marked a turning point for the country. Today, as the democratic movement continues to evolve, Sharpeville is once again in focus – this time as a centre for regeneration. Sedibeng District Authority plans to create a fitting legacy for the site and has commissioned Arup to undertake a number of studies for the project, including the creation of a cultural precinct around the Sharpeville Memorial.

▶ Sharpeville is hugely important to the development of South Africa. The massacre acted as catalyst for a lengthy period of active and armed resistance to oppressive rule, and also marked the start of the country's long isolation from the international community. With the largely peaceful transition to democracy resulting in general democratic elections in 1994, South Africa continues to revere Sharpeville as a symbol of the struggle. The anniversary of the massacre has been commemorated as an official public holiday – Human Rights Day – since 1994. The significance of Sharpeville was further highlighted when it was selected by Nelson Mandela for the signing of the new Constitution of South Africa, on 10 December 1996.

Today, Sharpeville remains an economically deprived but unified community. People live in a mixture of shacks and social housing, often built haphazardly as money filtered into the district. The police station, where the massacre took place, still stands, heavy with symbolism. Traces of the event can be seen in the urban landscape: a memorial, museum and precinct, where churches from nine different religions sit together in a circle. Here, strong social, political and cultural elements exist side-by-side.

The challenge for Arup was to create a plan that celebrates and commemorates the human rights movement, paying homage to past events while looking to the future. The new scheme should act as a catalyst for regeneration, attracting private investment and job opportunities to the neighbourhood.

The Arup team began by arranging a series of workshops with representatives of the Sharpeville survivors' group, the local library and the youth forum – together with other residents. These workshops explored how to achieve such multiple objectives while remaining relevant to the local culture. Frank and open discussions revealed the many sensitivities important to the local community. It soon became clear that respecting heritage was utterly vital, alongside economic opportunities.

A closer exploration of heritage revealed how powerful locations themselves can be in terms of both symbol and meaning within local storytelling. The community was keen to see storytelling embodied in the new proposals, allowing people to share their messages with dignity. The Arup team developed concepts for a holistic urban regeneration process within the community, in a continuing dialogue with residents ▶

▶ The Arup proposal restructures Sharpeville's residential area, linking it with the Sharpeville memorial and church precinct to create a 'Heritage Hub'.A pedestrianised street – the 'Heritage Promenade' – has active retail and workshop frontages linking the community hall with the memorial. Low- and medium-income housing flanks the promenade as part of the general streetscape upgrade.

The existing museum, memorial and library quarter are rejuvenated and expanded to integrate the Sharpeville Police Station into the memorial area. In addition to refurbishing the existing museum and community centre, an iconic Human Rights Museum will be built. It will house a research centre, archive, and temporary exhibition centre – all built around a new Human Rights Square. Cafés and shops will be incorporated, along with facilities for visitors, including the current arts and crafts market.

The Heritage Hub will be visually and physically connected to a Sports Community Hub. The town's Community Hall will be redeveloped to create a multi-purpose venue for uses including theatre, cinema and banqueting. These innovative schemes were developed with reference to best-practice heritage sites in Africa and internationally, including Johannesburg's Constitutional Court, Port Elizabeth's Red Location Museum and Jerusalem's Yad Vashem Holocaust museum.

Decision-making for regeneration schemes in South Africa is consensual and collaborative: Arup's proposal has been approved by the Sedibeng District Council and has been developed in consultation with affected communities, during the annual public participation process for local development plans. Arup led this process, providing its unique blend of masterplanning, architecture and urban regeneration skills. National Funding will assist Sedibeng District Council in taking the project forward, together with government and private-sector investors.

Arup has successfully responded to the challenges of this culturally significant site through adoption of the correct scale of intervention, going beyond traditional 'museum' concepts to create a symbolic site, imbued with meaning and integrated into a living community.

In the words of Arup client Lisa Seftel, City Director for the Sedibeng Municipal Authority:

"Sharpeville is associated with the struggle for human rights and freedom in South Africa. It is thus fitting, as we move towards the 50th anniversary of the 1960 Sharpeville Massacre, that there are projects which appropriately remember this struggle; and create a legacy for past and future generations." ■

Project
New York State Pavilion – Arts in Motion
Location
Queens, New York, USA
Client
Emerging Green Builders of New York, New York Parks Department

◀ New York State Pavilion – Arts in Motion

Talent of tomorrow

The Emerging Green Builders 2007 Natural Talent Design Competition gave free reign to Arup's new graduates to design on a park-wide scale. When they reviewed their winning entry, the team was surprised to find that in just a short period of time, Arup's holistic approach to design was ingrained in their way of working. It made their entry stand out from the rest.

▶ The space-age towers and circular canopy of the New York State Pavilion stand abandoned in the middle of New York's Corona Park, a remnant of the 1964 World's Fair. The theme of the Fair was 'Man's Achievement on a Shrinking Globe in an Expanding Universe', making the structures fitting symbols for the borough of Queens, which is home to people from over 100 different nationalities.

The 2007 Natural Talent Design Competition was sponsored by Emerging Green Builders, part of the US Green Building Council. It set young engineers and architects in the New York region the challenge of bringing this derelict site up-to-date by transforming the Pavilion into a performing arts centre.

The design had to aim for high sustainability standards and consider the entire park, as well as the vibrant community of Queens.

The design team partnered structural and acoustic engineers from Arup with architects at Atelier Ten and Cook + Fox. The site's existing structures are so iconic that the team decided not to disturb them. Instead they sheltered the performing arts centre beneath a 'Tent of Tomorrow'. This is a 350 x 225 foot elliptical structure designed by Philip Johnson. It has sixteen 100-foot high columns that at one time supported a coloured canopy of plexiglass panels. They wanted to preserve the iconic architecture of the site while designing a new space to excite the community and re-energise this area of the park.
The team made the early decision that each piece of the site should be interlinked, and that each design decision should influence several areas of the project. This holistic approach can be seen in every element of the design.

The park gets surprisingly little foot traffic as a result of the flat and uninviting landscape. In order to create a more welcoming atmosphere to entice more people into the park, the team designed a series of rolling hills around the performing arts centre. The new landscape also allows rainwater to be collected for irrigation and flushing toilets, while screening the traffic noise of the adjacent parkway. ▶

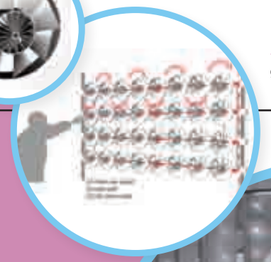
▶ The team used the same contours to add a skateboard park, legitimising the current practice of performing stunts within the park's empty fountains. By placing it close to the arts centre, they hope it will lure young people into participating in community events.

Using the existing columns as a framework, a huge windscreen transforms the Tent of Tomorrow into a small-scale power plant. The screen is made up of thousands of lightweight micro-turbines that provide enough electricity to operate the entire complex. Any surplus energy would be sold to the city's electrical grid. The team had the innovative idea of using some of the electricity generated to activate light-emitting diodes. In this way, the windscreen would become a self-powered light-sculpture. While many works of art were lost from the Pavilion, including contributions from Andy Warhol, the sculpture brings a sense of public art back to the site and creates a bright focal point for the local community.

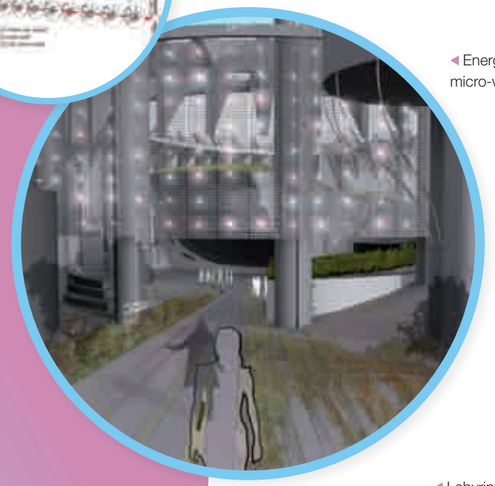
Inside the arts centre, the green roof provides a blanket of sound isolation, shielding audiences below from aircraft noise – a flight path runs directly overhead. The existing basement is converted into a labyrinth air treatment centre. This uses geothermal heat pumps to maintain a constant temperature inside the centre. Outside air is passed through the concrete walls of the labyrinth before entering the conditioning system – rubble from the site demolition fills metal cages to form the walls of the labyrinth, further helping the centre's sustainability credentials.

Completing the new performing arts centre is an organic café, perched in one of the New York State Pavilion's existing towers. It will be a spectacular spot to enjoy the sweeping views of the surrounding park, city skyline and the new public space below.

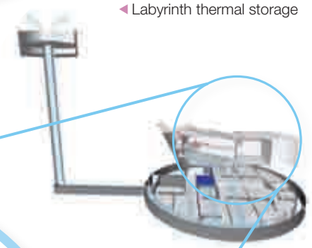
The judges said that Arup´s winning team "brought a level of holistic design to their entry that other teams failed to deliver". While this was not something they had deliberately intended, it seems Arup's approach to design is inherent in their work after only a few years with the firm. Though no formal plans for the future of the Pavilion currently exist, members of the Arup team have been asked to meet with Park's Department officials to present and discuss their design ■



◀ Renewable power generation mechanics



◀ Energy generating micro-wind façade



◀ Labyrinth thermal storage

◀ Acoustics and theatre design

Project
drawing water challenge – Ideas competition
Location
Global

▲ The dew-catcher, 'WatAir' is now at prototype stage, and its designers are in discussions with manufacturers.

▲ A means of purifying water while transporting it is ideal for remote communities.

Creative **flow**

What links a dew-collecting pyramid, an idea for re-deploying unwanted bicycles to speed-up water pumping at bore holes, and a concept for an openwater system for South Asia's urban areas, to provide clean domestic water, storm run-off treatment and recreation space? The answer is the drawing water challenge – a global 'ideas competition' masterminded by Arup and supported by WaterAid, the international charity.

▲ Idea for harnessing pedal power to pump water more easily from wells and bore-holes.

▶ One billion people do not have access to safe water, while two-fifths of the planet's population lack adequate sanitation. Arup and WaterAid decided to organise a global ideas competition to encourage original thinking and innovative solutions. Anyone in the world could participate.

The challenge was to create a new concept, technology, product or innovation that could help solve the lack of clean water or sanitation suffered by so many in developing countries. With over 100 entries from 19 different countries, the sheer diversity and creativity of responses was inspiring. The competition unearthed some highly original concepts, which may prove significant in improving access to water for people in the developing world.

Ultimately, first prize was won by two Israeli architects, Joseph Cory and Eyal Malka. They conceived 'WatAir'– an inverted pyramid array of lightweight dew-collecting panels, collecting more than 45 litres of water each day from the air. They have since developed a prototype and are in discussion with manufacturers. Maxime Hourani from Lebanon took second prize for her immensely practical idea of harnessing pedal power to help pump water more easily from wells and bore holes. Christoph Wust and Eva Nemcova of Germany won third prize, for their openwater system concept for urban areas in South Asia, which incorporates an effective rainwater runoff treatment, the supply of clean water for domestic use and recreation space.

Other ideas have surfaced as successes in their own right. One is a water carrier that purifies water as it is pushed along. With its potential to provide remote communities with a device that both transports and purifies water, the 'Reverse Osmosis Sanitation System' attracted praise and £50,000 of funding from investors when it appeared on *Dragon's Den*, the flagship BBC entrepreneurial programme.

Arup has always championed creativity and innovative thinking among its own people. Its inaugural public competition encourages and rewards original thinking in those outside the firm too, helping to find solutions to one of the biggest problems facing mankind ■