Foresight ◤ Innovation ◤ Research ◤ Sharing ◤ Training

Issue 1 2016

FORGT

Ribbon Chapel: realising the metaphor of lifetime love

Welcome

Welcome to the inaugural issue of FIRST, an Arup magazine which takes a close look at the cutting edge of the built environment.

Arup strives to deliver new thinking and design and technical excellence in support of our clients' projects and aspirations. At the heart of this commitment is Arup University (AU) which, unlike conventional corporate universities, offers a wide range of services and resources to help both our staff and the wider industry to explore fresh ideas, sharpen new skills and share knowledge across disciplines.

AU follows a unique model which, as inspiration for the name of this magazine, involves **F**oresight, **I**nnovation, **R**esearch, **S**haring and **T**raining.

We have a 3-phase approach — Now, New, and Next:

Now: Sharing and training focus on current business needs. Our experienced engineers are trained and accredited to deliver technical courses which are shared globally within Arup and will soon be available to our business partners. Seminars and workshops are held regularly, both internally and externally, to share the latest technologies with our staff, our clients and the wider community.

New: Research grows new ideas and develops innovative technologies/ products. Arup delivers outcome-focused research as well as practical services in strategic research planning. We do this in response to our clients' challenges, in partnerships with academia and industry worldwide.

Next: Foresight explores future trends. We help our clients understand the emerging trends affecting the built environment, explore new ideas and think more comprehensively about the future and how to manage opportunities, risks and uncertainty.

We hope you enjoy reading it and find it valuable. If you have any thoughts, questions or comments, please contact us at **ea.arupuniversity@arup.com**.

Arup University

Ribbon Chapel: realising the metaphor of lifetime love

The Ribbon Chapel is a wedding venue located on the grounds of a resort hotel in Hiroshima, Japan, overlooking the Seto Inland Sea. Inspired by a flying ribbon, two spiral staircases start at different locations before ascending and connecting at the 15.3m high rooftop platform to form a single ribbon, symbolising two paths ending in marriage. The intertwining stairways also form the roof, eaves and walls, enclosing the central space that can seat up to 80 guests.

Supporting each other

The free-form design with the 'floating' staircases presented some unprecedented structural challenges to the Arup team. Firstly, the structure can be regarded as a coil spring that could twist and expand outward while moving vertically with pressure from above. Arup's solution to stabilise the movement was to connect four points where the inner and outer spirals cross paths. This created a three-dimensional bracing system to restrain the outward swell, and an overall tube-like structure to resist horizontal forces.

Client:
Hiroshi Nakamura & NAP Co Ltd.

Arup's scope of services:
Structural engineering, geometric engineering, MEP engineering, lighting design and acoustics

A wedding venue whose ribbon form is symbolic of its function

Vertically, the building is supported by a series of load bearing steel posts 100mm in diameter. Without impacting the aesthetics, the steel posts only support the inner spiral while the outer spiral is coupled to the inner spiral in the form of an overhang.

As a result, the two spirals mutually support each other and create a self-standing structure. We believe this is the only structural system of its kind in the world.

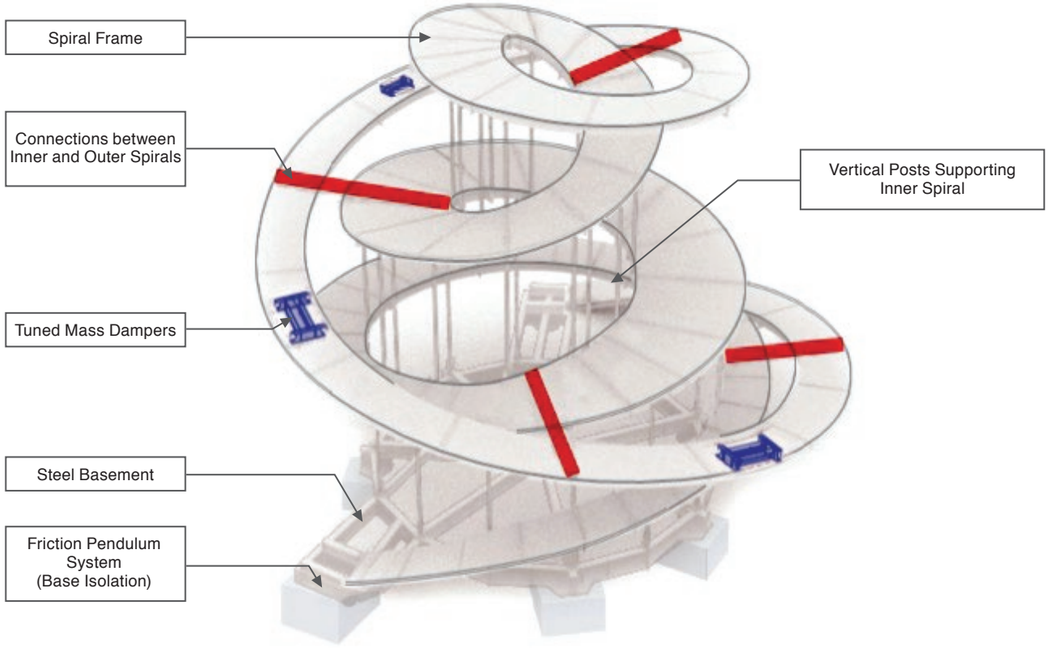
Standing firm

Since the Ribbon Chapel is located in an earthquake zone, the Arup team also had to cope with vibration and seismic activities. A friction pendulum-type base isolation system was installed to reduce seismic forces and to increase durability of the building, so that it would not be necessary to modify the form, system, regulations or material specification to ensure a stable and safe building but still preserve the original design intent.

In addition, cantilever-type tuned mass dampers were installed at three points on the outer spiral where the floor's natural vibration frequency was under 8Hz. The tuned mass dampers reduce footfall-induced vibration to ensure visitors' comfort.

'Twisting' back

The design team estimated that when the falsework was removed after completion of construction, the building would undergo a maximum of 32mm in rotational displacement induced by self-weight of the structure, causing the vertical support posts to lean. Therefore the support posts were deliberately slanted during construction by the same degree of rotational displacement, but in the reverse direction. As a result, after the completion of construction the posts would 'twist' back to vertical, and stayed within a minimal margin of construction error between levels.



Structural components

Spiral ceiling

Efficiently precise

The spiral stairway comprises two steel tubes each approximately 280m long, with steel floor plates mounted on them. In order to reduce cost and construction time, the spiral steel tube which had originally been designed as a single uninterrupted free curve was redefined as a combination of 88 joined sections of two-dimensional curved steel pieces, each with a maximum variation allowance of 10mm, creating an apparently seamless three-dimensional free curve.

In conjunction with the oculus skylight, windows along the stairways provide an abundance of natural light to the interior. All the windows vary in height, thickness and shape, and each joint of their glass panes varies in angle. In anticipation of the rotational displacement of the structure due to the self-weight load, the glass panes were produced by measuring the actual size of all openings. Furthermore, to protect the glass panes from the three-dimensional torque of the structure during earthquakes or strong wind, they are secured with dot point glazing fixtures, allowing them to move freely during torque produced by horizontal forces.

The Ribbon Chapel seamlessly integrates architecture and engineering to create a building of unprecedented composition. The project has bagged multiple honours, including the Overall Winner of the LEAF Awards 2015, the Grand Award of Japan Commercial Environment Design Association Awards 2014, the Japanese Society of Steel Construction Outstanding Achievement Award 2015, and the Japan Society of Seismic Isolation Award 2015. Project Director, Ikuhide Shibata, received the Japan Structural Design Award 2015 for his contribution to realising this unique structure.

Client:
CLP Power HK

Arup's scope of services:
Geotechnics, structural engineering, metocean modelling and analysis

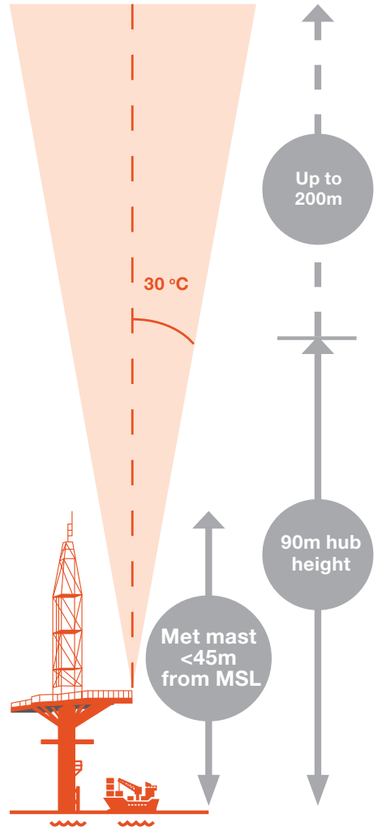
CLP offshore wind farm: pioneering the 'suction can' foundation

Arup was commissioned to design an offshore meteorological mast to collect wind and wave data for the feasibility study of a wind farm in the south-eastern waters of Hong Kong.

The met mast used LiDAR to detect wind speed and direction using laser beams, and can measure wind speed at hub height or beyond of the future wind turbines, 90m above mean sea level and up to 200m.

The met mast foundation and its installation presented an unprecedented technical challenge as there had been no previous offshore projects in Hong Kong. The mast needed to be installed in 30m of water over soft marine clays and medium dense alluvial sands, with wave heights up to 16m in a 50-year typhoon. The installation needed to be carried out in summer for a calmer sea state in general. However, it was also the typhoon season, therefore the installation period needed to be short (3-4 days) to limit the exposure to weather risks.

Other design constraints include the Environmental Impact Assessment requirements to minimise noise, dredging and disturbance to seabed. Furthermore, the wind farm structures are required to be decommissioned and completely removed from the seabed after their 25-year design life.



The met mast collects wind data

Facing these design constraints and requirements, the Arup geotechnical engineers sourced inspiration from their colleagues in oil and gas engineering, and proposed the use of the 'suction can' foundation, a technology typically used in offshore oil platforms and deep seabed anchors for large carriers.

The key benefit is that no dredging or pile driving is required, thus reducing the associated environmental impact, and the suction cans may be removed completely from the seabed at the end of their use. Furthermore, installation is fast and safe, thus minimising weather risks and resulting in cost savings.

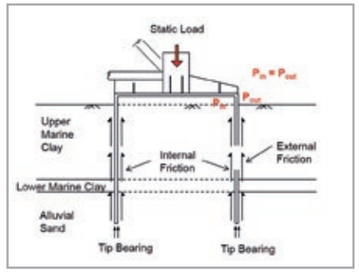
The installation sequence was carefully designed. The met mast was first lowered vertically onto the seabed by a heavy lift crane barge. The 'suction cans' then sank into the seabed under their own weight during which the free water in the cans escaped through the vent valves at the top. When the 'suction cans' would not penetrate further under their own weight due to resistance from the soil, suction was applied by pumping water out of the cans using submersible pumps, thus creating a pressure differential across the top of the can, pushing them further into the seabed to the final founding level.

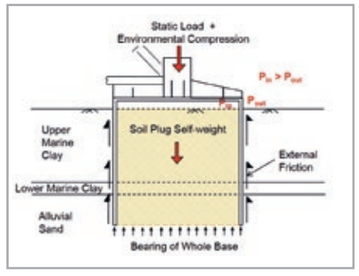
Different load transfer mechanisms were considered in the design depending on the loading conditions:

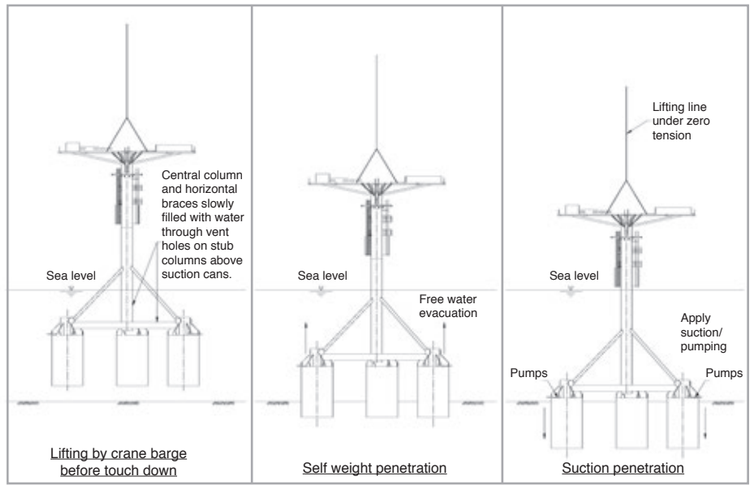
- Under Static Compression: The resistance to the load is provided by internal and external wall friction and bearing on the wall tips.
- Transient Compression: The 'suction can' is pressed against the soil by waves. Water is unable to drain out through the soil plug quickly, and the load is resisted by external wall friction and bearing on the full base area.
- Transient Tension: The 'suction can' is pulled from the soil by waves and a cavity develops between the soil surface and the top of the can. The transient tension is resisted by external wall friction and the weight of the suction can and soil plug.

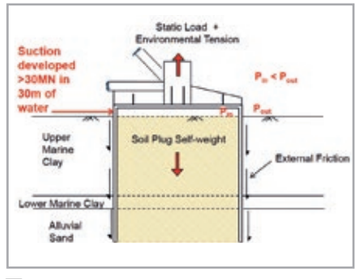
The met mast 'suction can' tripod was fabricated as a single 800-tonne structure, with steel cans 7m in diameter, and was successfully installed within four days with the suction installation of the foundation taking less than an hour. Since its installation the met mast has performed well in severe typhoons and no permanent tilt or settlement has been detected.

The project marks the first time that the 'suction can' foundation system has been used in Hong Kong and also the first time used in wind farm structures worldwide. Our quick and easy solution has simplified the installation process and achieved significant project cost savings, benefitting the overall financial viability of an offshore wind farm in Hong Kong.









Different load transfer mechanisms

Foundation system installation sequence

Client:
Development Bureau of the
Government of the Hong Kong SAR

Arup's scope of services:
Transport consulting

Kwun Tong: transforming into a business area

Long recognised as one of Hong Kong's traditional industrial zones, Kwun Tong has been transforming rapidly over recent years as office and commercial buildings gradually take root in the area. Many industrial buildings are also taking up new roles, attracting small and medium enterprises and the creative industries. In 2011, the Hong Kong Government announced plans to transform Kowloon East, an area comprising the Kwun Tong Business Area (KTBA), the adjacent Kowloon Bay Business Area and the Kai Tak Development Area, into a second Central Business District to sustain Hong Kong's economic development. The Energising Kowloon East Office (EKEO) was specially established to monitor the progress of the project and organise various public engagement events to maintain a close dialogue with the community – a first time in Hong Kong.

A key theme of the improvement plan is to promote a walkable Kowloon East. Due to its industrial past, Kwun Tong and its vicinity were developed with a priority for vehicular traffic, with plenty of loading/unloading areas along the roads, and relatively narrow footways. These facilities can no longer cope with the escalating pedestrian and traffic flows being generated by this transformation and they are also restricting the future development of the area.

Since May 2014, Arup has been leading the transport consultancy work for the Pedestrian Environment Improvement Scheme for KTBA. Our main task is to review and assess the pedestrian and traffic environment and propose feasible schemes to enhance pedestrian connectivity, walkability and road safety in the area.

Our solutions have not only devised a framework and vision for improving the pedestrian and transportation network in KTBA (and Kowloon East in general), but also incorporate 'place-making' strategies to rejuvenate the area. In addition, since Kowloon East has been highlighted by the Chief Executive in the policy address as a pilot area to explore the feasibility of developing a smart city, 'smart solutions' were also incorporated into our proposal. Our smart city concepts are more than just information and communications technology (ICT) enhancements in the built environment, but also encompass mobility, living and environment smarts.

Our place-making approach starts with many simple yet effective quick-wins at 'test points', referred to as 'acupuncture' by the project team, which enable the public to benefit immediately from the improvements. A highlight of these measures is promoting back alleys as pedestrian corridors. Kwun Tong has a unique back alley network between industrial buildings. It was previously used for loading/unloading but has been underutilised in recent years. By revitalising these wide back alleys, they can provide a third layer to the current road/pedestrian network and relieve the pavement congestion on adjacent main streets during peak hours.

In our pilot scheme for improvement to attract more pedestrians, we introduced street art in selected back alleys with graffiti and artwork by local students, artists and NGOs. The street art also provides an orientation and way-finding system to the often maze-like back alley network. Additionally, we collaborated with local streetathon organiser RunOurCity to host night run parties to promote the back alleys and encourage the public to get familiar with the system.

We believe that there are a lot of opportunities to cooperate with various stakeholders to add vitality to the back alleys and thus embrace social inclusion in the process of improving the neighbourhood.

In line with the EKEO's preliminary smart city strategy to make better use of innovative ICT for a more convenient life, we also proposed several smart transport management solutions. These included setting up smart logistic lockers that provide a quick and easy service option for both recipients and senders, thus lessening the loading/unloading activities. We also suggested that 'Hong Kong eTransport Information Service' be available at the electronic information platform in shopping malls and commercial buildings in the district.

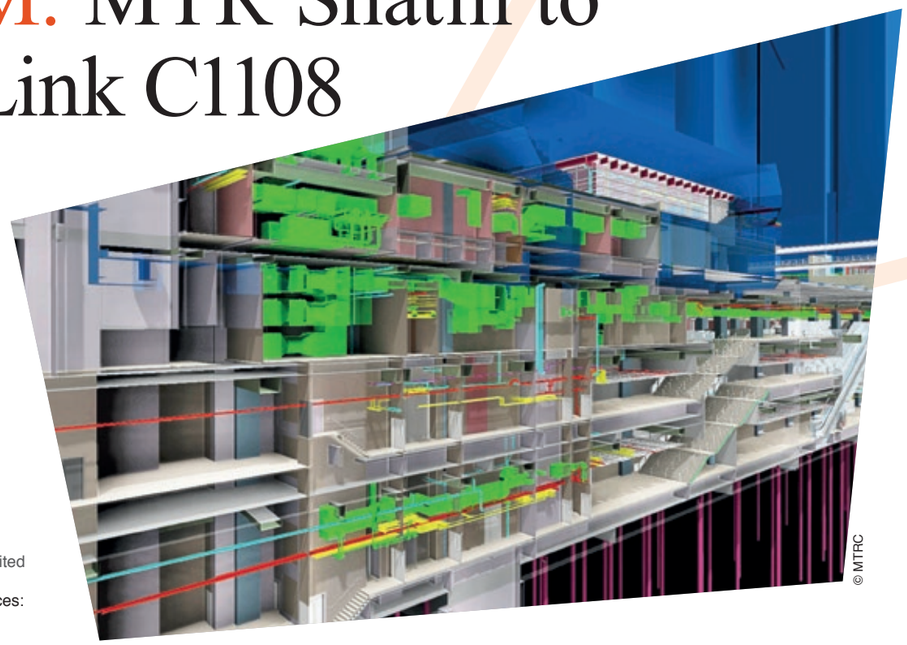
Public views on our initial study findings and improvement strategies were collected on the client's website using an interactive map jointly developed by our Management Consulting, Transport Consulting and GIS teams. Different stakeholders can identify problem areas by a simple click on a map and then entering their comments. This allows us to collect public feedback to formulate our proposals and further refine our solutions.

By incorporating smart city and place-making strategies into our work, our integrated planning approach is not only helping to create a quality pedestrian environment in KTBA, but also revitalising the area into a vibrant, green and people-oriented Central Business District. We shape a better KTBA.

Interactive map for public engagement

Street art was introduced to the back alleys to add vitality and also provide a way-finding system

Managing complexity with BIM: MTR Shatin to Central Link C1108



BIM model showing multidisciplinary integration

Client:
MTR Corporation Limited

Arup's scope of services:
Rail engineering

The Shatin-to-Central Link (SCL) is a strategic 17km rail extension interfacing with existing lines in several districts of Hong Kong which will give passengers a wider range of travel options and improve Hong Kong's overall railway network.

Arup serves as lead consultant for the major multidisciplinary Agreement No. C1108 for the construction scoping and sequencing of the Hong Kong section, including construction of the new Exhibition Station and interchange facilities, 1.8km of twin railway tunnels and ventilation buildings and shafts in Wan Chai – one of the most built-up and busy commercial areas in the city.

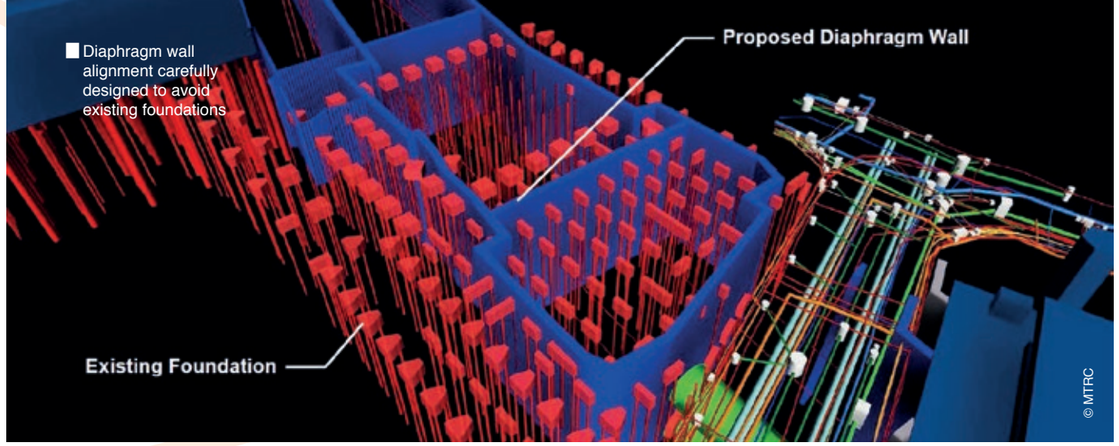
Unlike typical BIM projects which involve buildings, BIM was used in the C1108 project to help identify potential problems in underground works, coordinate traffic management schemes, and facilitate construction sequence planning to ensure timely delivery.

The project is highly complicated with various elements

Minimising impacts

The complexity of the project posed major challenges to the project team – limited work sites and numerous interfaces. The team had to prepare the temporary traffic management plans, work with existing structures and underground utilities, and coordinate with another major infrastructure project, the Central-Wan Chai Bypass (CWB), whose work areas overlap with this project. Adding to the complexity is the demolition and reprovision of community facilities, whose foundations overlapped with the diaphragm wall alignment of the new station.

A large-scale BIM model was created to integrate GIS data from multiple sources and formats, and consolidate the information with the proposed station, tunnels, public facilities and as-built records of the adjacent buildings. The model offered an integrated solution and holistic view of the entire construction sequence, so that temporary traffic management schemes could be scheduled and co-ordinated, helping to facilitate smooth construction and ensure effective project implementation. It also enabled the project team to gain greater insights into possible conflicts, impacts and logistical constraints.



To make room for the new Exhibition Station, the Harbour Road Sports Centre and Wan Chai Swimming Pool were demolished and relocated before the station can be constructed. Since the existing foundations of the sports complex overlapped with the diaphragm wall alignment of the new station, a typical solution would be removing all foundations before installation of the diaphragm wall.

With the help of the BIM model, the design team was able to accurately locate the existing piles and foundations, and designed a diaphragm wall alignment that would avoid these piles as much as possible. This has minimised generation of waste and saved considerable time and costs.

BIM also helped in the coordination with the CWB project. It integrated information from the adjacent projects and allowed the C1108 team to analyse impact on their design. Subsequent updates were easily imported, effectively improving understanding of potential impacts and enabling the C1108 team to either make necessary design changes or return comments to the CWB team in case of major conflicts, thus facilitating the checking process for effective project performance and delivery.

Seamlessly integrated

As the interchange station between the SCL and the future North Island Line, the new Exhibition Station will house a number of building services and system installations to support railway operations, including the tunnel ventilation, traction power system, and operation and signalling systems. All these require structural and architectural provisions to accommodate them.

BIM enabled the production of fully-coordinated construction drawings, allowing Arup designers to plan and review space arrangements for the architectural, structural and building services elements. Clash analysis greatly helped the design team to identify discrepancies between various disciplines so that engineers could coordinate and resolve issues well in advance of construction, thus minimising actual conflicts and rework on site.

Better see and understand

The BIM model was also useful for counter-checking information provided by other parties, such as survey records from sub-contractors. Information was imported to the BIM model and converted into 3D visualisation, useful in verifying the vertical profiles of the utilities to ensure design feasibility.

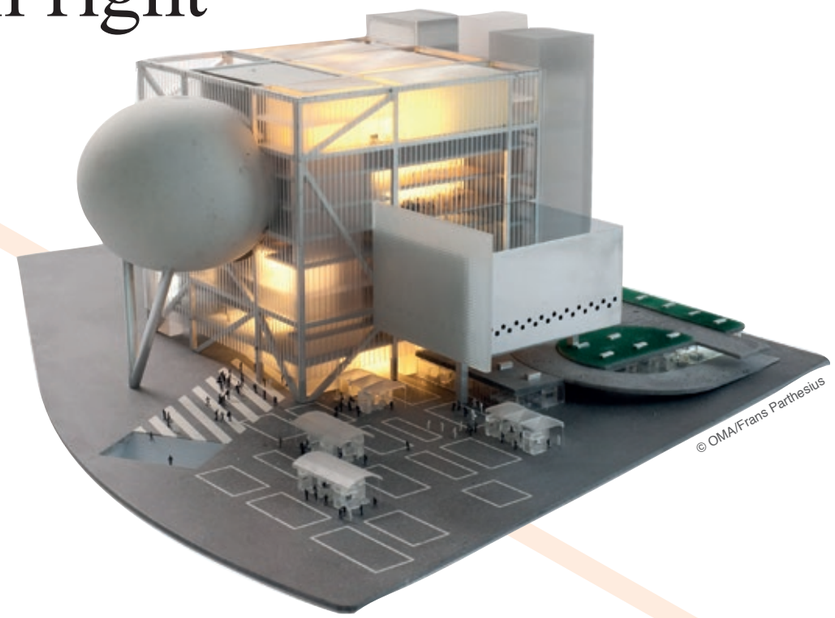
The vivid 3D images and animations generated from the BIM model also helped the design team to communicate the construction sequence effectively with the client and stakeholder groups (including government departments, the district council, and adjacent building owners and tenants), helping them to visualise the designs and understand possible impacts during the construction stage.

BIM played a vital role in tackling the unique challenges in this enormously complex project and achieving the desired quality and performance. As design team leader Timothy Suen reflected, "Without BIM, this particular project would have been very tough. It helped to minimise design inconsistencies from the start, with problems being mitigated efficiently."

The MTR C1108 Arup team was honoured with the 2015 Autodesk Hong Kong BIM Award, as well as First Place for 'Excellence in Infrastructure' at the international 2015 Autodesk BIM Awards.

The new Exhibition Station

Taipei Performing Arts Centre: a piece of art in its own right



Client:
Taipei City Government

Arup's scope of services:
Structural engineering, fire engineering, building physics, MEP engineering

Inspired by a traditional Chinese wood block puzzle, the Taipei Performing Arts Centre (TPAC) is an international standard performing arts facility. The centre will include a 1,500-seat Grand Theatre, an 800-seat Multiform Theatre and an 800-seat Proscenium Playhouse.

The TPAC design, by the Office for Metropolitan Architecture (OMA) with Arup advice on structure, MEP, building physics and fire engineering, was the winner of an international design competition in 2008. The two key architectural design concepts are:

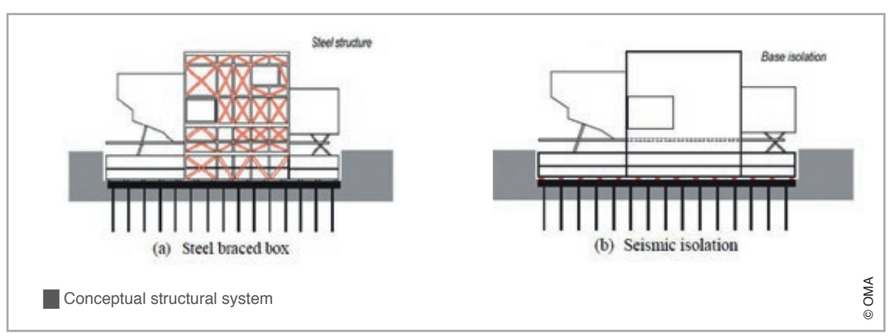
- To create a new type of theatre by linking the auditoria and therefore allowing alternative stage configurations to create unique performance spaces
- To raise the auditoria in order to free up the ground floor and create public space in a busy city centre site

The three auditoria are plugged into and cantilevered from a central compact cube, combining the stages and backstages of the three theatres into a single and efficient whole. This enables each theatre to be used independently or in combination with the other theatres. A public path inside the cube exposes parts of the backstage areas that would normally be hidden to visitors.

Realising the structure

These architectural design concepts posed several challenges for the Arup team. Firstly, since the Taiwan region is highly seismic, earthquake performance of TPAC is the highest structural priority. In particular, being an important public facility, the TPAC must achieve hospital (i.e. mission-critical) performance level and must achieve immediate occupancy after a severe earthquake.

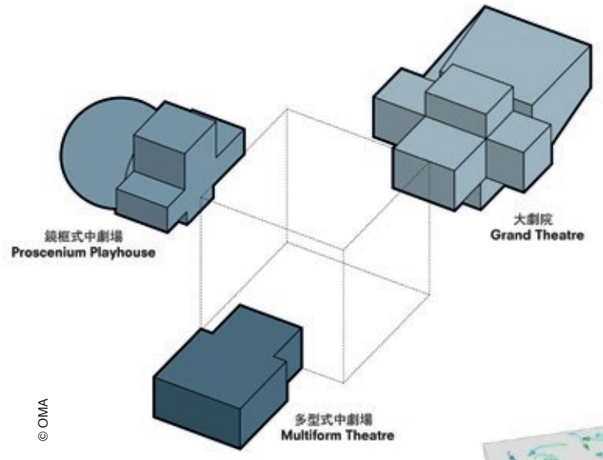
Due to the building's complex geometry, irregular mass distribution and high performance requirements, the design team decided to create a laterally and torsionally stiff braced box around the perimeter of the cube to carry all lateral loads and much of the gravitational force (Fig. a). This frees up the interior allowing flexibility in planning the theatre spaces. And, in conjunction with additional auditorium columns, the stiff braced box will support and stabilise the three projecting volumes of the theatres and provide good lateral and torsional stiffness.



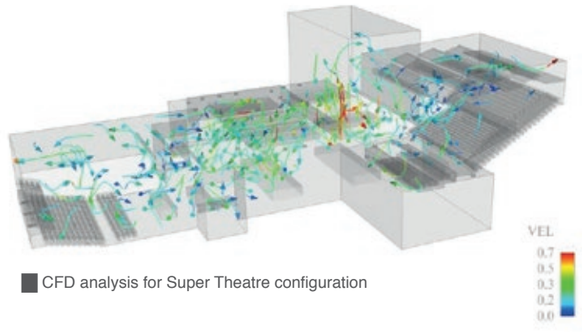
In addition, the Arup team decided that the only feasible solution for achieving the necessary (immediate occupancy) performance given the level of seismicity in the region would be to use a base-isolated structural system to attenuate the transmission of ground motions into the building during a severe earthquake (Fig. b). Analysis indicated that the seismically isolated structure using a friction pendulum bearing system met and surpassed the performance objectives while achieving a 60% reduction in the base shear and significant decrease in the storey drift and floor accelerations, thereby minimising seismic damage to the TPAC structure and its finishes over the lifetime of the building. This was the first use of friction pendulum bearings in Taiwan.

Safe and comfortable

The architectural design concept of combining the auditoria also posed big challenges for fire engineering and ventilation. In the Super Theatre configuration, the two main theatres will be connected to create a giant auditorium with a 60m long central stage. The changing permutations of theatre space and seating layouts make it difficult to maintain a high-level of environmental quality and impossible to be fully compliant with the local prescriptive code in terms of fire separation.



Three theatres plugged into a central cube

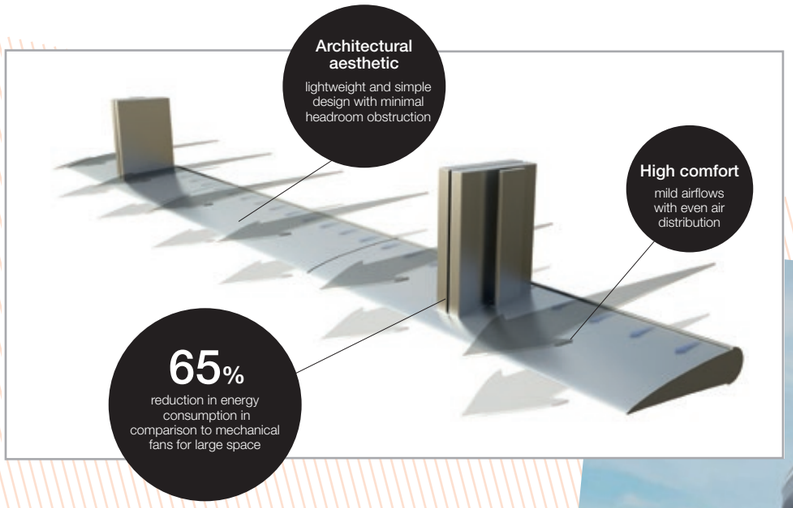


CFD analysis for Super Theatre configuration

Our Building Physics team designed for the theatres separately and then carried out computational fluid dynamics (CFD) analysis to assess the airflow through the auditorium and stage areas in various configurations. The analysis took into account the varying needs of audience and performers, as well as the location and speed of air supplies (e.g. fast air movements could provide improved cooling but would risk movement of stage curtains and props). The CFD results confirmed that, even in the Super Theatre mode with HVAC systems of very different natures operating adjacent to each other, our ventilation strategy would still achieve satisfactory levels of occupant comfort.

Similarly, fire dynamics simulator (FDS) analysis was carried out to study fire and smoke propagation. The results demonstrated that regardless of the theatre configuration used, the building could be evacuated safely in the event of a fire without conventional fire separation methods such as enclosing the central stage area with fire shutters. The rationalisation of the building escape routes allows the theatre seating arrangements to be optimised, the number and width of staircases to be reduced and the travel distance to be extended. This solution creates a more open and integrated space in the building and increases the number of seats, hence providing more revenue for the client. And, by demonstrating a performance-based design, our comprehensive fire strategy successfully convinced the authorities that our design meets the best safety standards despite the deviations from the Taiwan building codes, creating a path for other complex buildings in Taiwan.

Upon completion (targeted for 2017), TPAC will provide Taipei with its first international standard state-of-the-art performing arts facility. The Taipei city council expects the centre to further facilitate the development of local performing groups, support indigenous performance art forms and add to Taipei's image as a global cultural hub.



With a minimalist design, the AIU improves human comfort in a more energy-efficient manner

Arup Ventures

Arup's Venturing Initiative seeks to commercialise products, software, apps and business ideas that contribute to designing a world that is safer, cleaner and more resource-efficient. Recently two products in East Asia have been designed with patents filed.

The City Air Purification System creates a cleaner, enclosed environment for waiting commuters

© Sino/Eventist

Bladeless is more: Air Induction Unit

The Arup invented Air Induction Unit (AIU) is an innovative device which combines form and function for ventilation in a semi-outdoor space.

A bladeless fan with an attractive minimalist design, the AIU uses aerodynamic principles to create a continuous but gentle, large-volume airflow to improve human comfort in a semi-outdoor environment.

Compared with traditional industrial fans, AIU can ventilate a much larger space with less energy. With no blades or other detachable parts, the device is quieter and safer in operation and easier to use, clean and maintain.

The simple design makes the device suitable for many applications such as restaurants and railway facilities. It has already been installed in a semi-outdoor restaurant area in The Green Atrium, a multi-purpose community centre in Hong Kong.

The AIU has won the Grand Prize at the Hong Kong Awards for Industries: Innovation and Creativity and received the Grand Prize under 'Category I: an invention' of the 2015 Hong Kong Institution of Engineers (HKIE) Innovation Awards for Young Members.

Tackling pollution at the roadside: City Air Purification System

The City Air Purification system, which takes the form of a bus stop, provides purified air to anyone standing inside it.

Jointly developed by Arup and Sino Green, the bus stop sucks in exhaust fumes from an inlet at the bottom, the air current then passes through a filter to remove pollutants before being pumped out of a louvre air vent overhead.

The system has been designed using the principles of fluid mechanics: the build up of positive pressure creates an air curtain that keeps pollutants out of the bus shelter. The air quality at the bus shelter can be monitored remotely.

The first prototype was set up in one of the busiest streets in Hong Kong where data was collected for two months. The empirical data demonstrated significant improvement in air quality through the system, with an average 50% reduction in the concentration of air pollutants. It was then moved to Beijing for testing, in collaboration with Tsinghua University.

Further planned enhancements include smart controllers to manage operating hours more efficiently, solar panels and energy floors to generate renewable energy and a mist cooling system for summer months.

The system won the second prize at the CIC Innovation Award 2015, in recognition of its achievements in research and innovative solution to tackle air pollution.

Future Air knowledge cards

We have recently developed the 'Future Air' knowledge cards which summarise the current challenges, efforts and solutions around air pollution in China. They are now available at

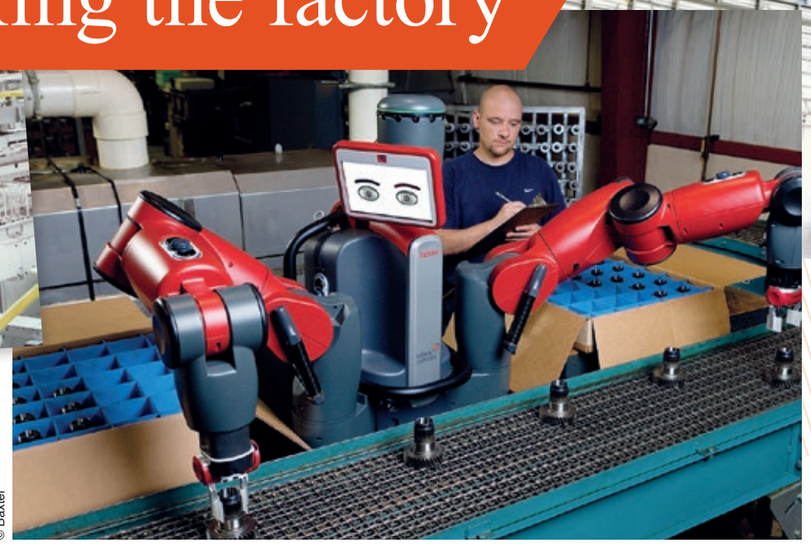
http://www.driversofchange.com/projects/future-air-knowledge-cards

Addressing air pollution tops China's agenda and the issue has also drawn international attention. Considerable effort has already been made to tackle the issue, such as industrial upgrading, clean energy, better transport fuel and setting higher emission standards. However, as the improvements have only been moderate, this suggests further collaboration across professions, industries and cities is needed to contain the problem.

The Future of Air cards are grouped in five categories: Social, Technical, Economic, Environmental and Political (STEEP). The cards serve as a source of inspiration to generate more discussions, ideas and solutions (such as the City Air Purification System) to combat air pollution in China.

The knowledge cards can be used in workshops to facilitate discussion and generate new ideas

Rethinking the factory



© Baxter

The University of Sheffield Advanced Manufacturing Research Centre with Boeing will be the UK's first fully reconfigurable assembly and component manufacturing facility

©AMCR / Bond Bryan Architects

The factory of the future will be optimised for humans and robots working together

© Local Motors Inc

Manufacturing has entered a new age of production, and shifting towards design and innovation processes that are increasingly fast, open, collaborative and responsive. As a result, the way factories are planned, constructed and operated will also change. Future factories and supply chains will have to operate at higher material and energy efficiencies, while providing safe and healthy working conditions for an increasingly skilled and diverse workforce.

An Arup report explores the future of the factory from three different angles: people, production and space:

- 'The Human Factor(y)' looks at the growing impact of technology on the workforce, including automation and the diffusion of cyber-physical assistance systems.
- 'Seamless Design and Production' focuses on the growing use of big data, insights and smart machines to optimise production processes and enable greater customisation of complex products.
- 'Resilient and Adaptive Spaces' focuses on the physical factory, looking at designs that are resilient to environmental risks as well as sustainable in their construction, operation and end of life disassembly.

While many people believe robots will replace humans in the factories of the future, the Arup's study suggests that collaboration between the two will be the key. Factory robots of the future will be able to safely interact and cooperate with human co-workers, who will serve as supervisors, combining the ingenuity and versatility of people with the precision and repeatability of robots. This will enable human-machine collaboration in dynamic and reconfigurable manufacturing environments.

The expanding 'Internet of Things' will also have a fundamental impact on the design and operation of factories and manufacturing processes. Intelligence based on big data and advanced analytics will create new opportunities for consumer insights and interaction. New technology such as 3D printing can reduce the amount of waste produced, increase energy efficiency and enable new levels of customisation. This will shift manufacturing closer to the end consumer and provide new opportunities for interaction between companies and their customers.

The future factories will need to be significantly more responsive to rapidly changing market dynamics and operational environments. Equipment will be flexible so that it can be readily adapted to manufacture multiple models within the same factory. Factories will embrace a freely interchangeable building system to enable rapid and efficient changes to layout, machine positions and function. They will also need to adapt to 'circular manufacturing', where products are returned at the end of life to be recycled and where waste is minimised

The 'Rethinking the Factory' report and other Arup's Foresight tools and publications are available at **www.driversofchange.com**.

Case Study: Local Motors 3D-printed Car

The vision behind Local Motors' driveable 3D-printed car is that consumers will one day be able to design their own cars online, then have the vehicle printed and delivered to their door. The company plans to set up two new 'micro-factories' and to start selling its cars in 2016. The long-term goal is that micro-factories will be located within 100 miles of major urban centers. This will help create local jobs, and will also reduce auto freight and distribution costs by an estimated 97% compared to typical automakers.

Drones for engineering and design

A UAV scanning the Dapeng Peninsula

Arup Shenzhen's Advanced Technology Group (ATG) and Architecture and Planning team are jointly exploring the technology of unmanned aerial vehicles (UAVs) for application to engineering and design projects.

It started as a response to the lack of data in China — a common problem for planners and designers there. However, at the same time designers and engineers are often challenged to provide more quantitative results to validate their work. This led the Shenzhen teams to identifying the need to collect their own data to reinforce design through data-backed results and reduce reliance on external data sources.

Traditional spatial capture technology is expensive and labour intensive, leaving room for human error. Comparatively, data-mapping drones are cheaper, more efficient, and have greater coverage and accuracy. However, professional drone surveying services are still too costly, preventing Arup projects from regularly using the technology. Developing an in-house drone service solves this problem as it enables us to deploy our own team and get the data quickly to our engineers at a significantly reduced cost.

The Arup project team partnered with DJI, the world's largest manufacturer of commercial drones headquartered in Shenzhen, to tap into their resources and expertise. The Arup team also established a partnership with Pix4D, an international UAV 3D image processing company based in Switzerland. Pix4D provides guidance to the team on generating accurate 3D models and digital surface models from the UAV captured images.

One of the first project implementations took place in the Dapeng Peninsula in Shenzhen. Arup was invited by the Shenzhen Mangrove Wetland Conservation to survey a 1.2km² area of a potential nature preservation district. Using drones, Arup was able to quickly capture and process information of the site in less than two days. The point cloud data was then converted into a 3D mesh model, and exported into data for further design and planning evaluation.

In the next project, Arup used drones on an active construction site in Qianhai (Shenzhen's newest CBD under development) to scan and monitor the construction process. A 14km² site was captured in just one day. Through drones, we have greatly increased efficiency and lowered risks for on-site engineers by scanning hard-to-access places.

Our prize-winning design for the Shenzhen International Low Carbon City also made use of drones to scan the existing low-carbon core demonstration area, and turned the point data into an interactive 3D model, which is then fully incorporated into the final masterplan.

UAVs are versatile and can be integrated into various disciplines. Uses could include:

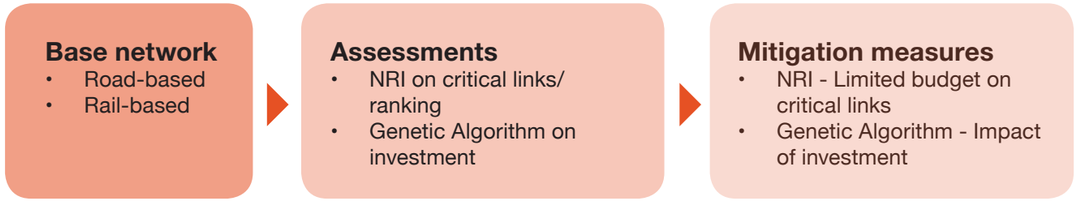
- Bridge inspection
- Façade inspection
- Traffic monitoring
- Post-disaster evaluation
- Environmental measurement
- Excavation volume calculations

The project team is now working on building an in-house environmental sensor with the help of Arduino and the Hong Kong Polytechnic University. The sensor is light and portable (about the size of an iPhone) and can be mounted on the drones to increase monitoring capability.

UAV site scan (top) vs final masterplan (bottom) for the Shenzhen International Low Carbon City

This research project successfully demonstrated that drones can save cost and time and fulfil a vital skill gap to provide engineers and designers with updated and state-of-the-art data. The project team is planning to apply their research results to different engineering solutions and provide drone data both as an in-house service and market it externally to our clients. The project is the winner of the 2015 Arup Research Awards under the 'Industrial partner collaboration' category.

Building transport resilience: a precautionary tool



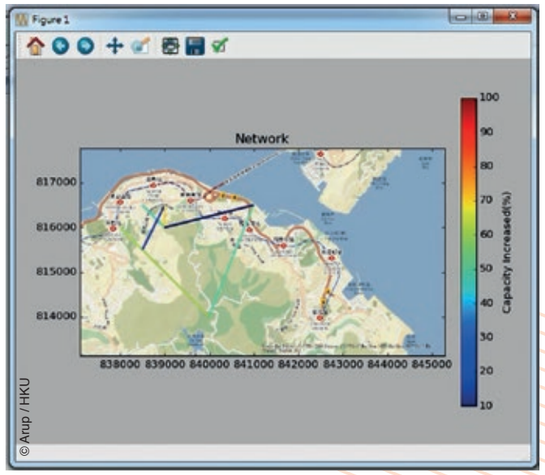
Study flow chart

Transport infrastructure is susceptible to disruption from both natural and human-induced events. Incidents such as traffic accidents, train operation failure and extreme weather can lead to structural or functional failures potentially disrupting traffic and the mobility of goods and people and harming productivity. Therefore, it is extremely important to minimise such impact and build resilience in urban transport systems, especially for densely populated and congested cities like Hong Kong.

The current practice in Hong Kong for impact assessment of transport infrastructure failure relies on prediction of the most-likely scenarios. However, the number of scenarios considered could be limited and results can vary greatly depending on the assumptions made by the planners. Although impact assessment methods have been used overseas, such methods are mostly developed for road systems and are, therefore, unsuitable for application to Asian cities where multimodal transport systems with dense and complicated public transport networks are the norm. Also, these existing impact assessment methods do not consider the network-wide impact such as the redistribution of vehicular and passenger flows after disruption.

Recognising the consequences of transport infrastructure disruption on daily lives and the need to develop a tool that can analyse the resilience of a transport network, Arup is collaborating with the University of Hong Kong (HKU) on a research project to develop a new tool to systematically assess transport infrastructure under disruption. Arup has been the consultant for the Hong Kong Government since 2002 on the Comprehensive Transport Study, giving us access to the transport data necessary for this study.

Disruptions in transport infrastructure can lead to chaos



Graphical display dialog of Genetic Algorithm results

The goals of this research are:

- To determine the maximum impact of each transport link (e.g. road or rail line) failure and hence to identify the critical infrastructure in the network
- To determine infrastructure ranking by importance
- To build resilience of urban transport systems cost effectively
- To assess key scenarios and develop incident management plans to minimise risk and ensure passenger safety

Overall NRI pattern of the Eastern District in Hong Kong

Our model methodology is based on the optimisation theory and existing vulnerability analysis available in literature. However, this is generally too complex for most practitioners, policy-makers, and engineers to manage. Our research has bridged this gap by developing a user-friendly software tool to help planners and engineers to systematically assess, identify and improve transport infrastructure resilience.

Two main indicators are used in our model: Network Robustness Index (NRI) and Genetic Algorithm. And the Eastern District in Hong Kong was chosen as the study case.

The NRI measures the change in the total travel time of all traffic flows in the network when a transport link is removed. The higher the NRI value, the more critical the link.

Our precautionary tool can help to identify the strategic connections (i.e. those with high NRI values) in the transport network, so that off-the-shelf incident management plans for the Transport Department, Hong Kong Police Force or transport operators can be developed in advance. When an incident/emergency occurs and a critical link fails, a response plan can then be deployed quickly to reroute traffic or divert passengers to other transport modes, thus mitigating the impact of the disruption. More importantly, the diversion will not severely affect other transport links or create additional failures. Further work could develop our current software into a real-time incident management tool.

Genetic Algorithm uses a process that mimics natural evolution to analyse different combinations of transport infrastructure capacities, and derives an optimal combination to minimise the average network travel cost. It can be used to compare the impact of investment on the total capacity in the entire network (a higher budget could allow existing roads to be expanded or new roads to be built), and provide the best solution to improve network resilience if budget is available. Our research is particularly appreciated by the Transport Department of Hong Kong and will help the Government to effectively allocate the limited budget to build and maintain transport infrastructure.

The research project has provided an opportunity to assess and understand key issues in the Hong Kong transport network. Likewise, similar evaluations can be performed for other densely populated cities, and will help to build resilience in the urban transport systems in those cities. The resilience model can be further extended to evaluate other infrastructure networks such as water supply, drainage or the national grid.

The research is supported by the Innovation and Technology Fund from the Hong Kong Government under the University-Industry Collaboration Programme.

Bioreactive façade: cultivating algae for energy

The BIQ house piloted the SolarLeaf façade system

A flat-panel glass bioreactor

A building's façade is crucial in reducing energy consumption. Intelligent façades can control light, shade, temperature and ventilation. As designers strive to create buildings with zero net energy, a new breed of façade — that actually produces energy — is emerging.

Arup has developed a bio-reactive façade system that harnesses the power of algae to create thermal energy and biomass. This SolarLeaf system, developed in collaboration with Colt International and Strategic Science Consult (SSC), uses flat-panel glass photobioreactors (PBRs) to create a controlled environment for cultivating micro-algae. The algae then photosynthesises in the sun, producing biomass. The solar thermal effect also generates heat.

The biomass and heat generated by the façade are then transported by a closed loop system to the building's energy management centre. The biomass is harvested through floatation and either transformed into methane off-site or made into pharmaceutical products.

The excess heat from the PBRs can be used for hot water, to heat the building, or storage for later use.

The advantages of biomass as an energy source are that it can be used flexibly for power and heat generation and can be stored with virtually no energy loss. Cultivating microalgae in flat panel PBRs does not require additional land-use and isn't unduly affected by weather conditions.

Furthermore, carbon emissions from conventional combustion processes are fed into the PBRs to encourage algal growth, preventing these carbon emissions from contributing to climate change. As microalgae absorb daylight, bioreactors can be used as dynamic shading devices, thus reducing the need for air-conditioning.

The SolarLeaf façade system was piloted in 2013 at the BIQ house in Hamburg, Germany, a 4-storey residential building designed by architects SPLITTERWERK. In total, 129 flat-panel glass bioreactors each measuring 2.5m x 0.7m have been installed on the south-west and south-east faces of the building to form a secondary façade. The panels take the form of louvers, supported on central vertical axes which can track the path of the sun. The system was designed to provide around one-third of the total heat demand of the 15 apartments in the BIQ House.

The efficiency of the conversion of light to biomass was calculated to be 10% and light to heat is 38%. For comparison, photovoltaic systems have an efficiency of 12-15% and solar thermal systems 60-65%. After two years of monitoring it can be confirmed that the system has a positive net energy balance, and in October 2015 the team implemented changes to the bioreactor-design to further enhance the overall performance.

As designers are increasingly seeking to create closed-loop systems for smart cities and provide ecosystem services through the built environment, bio-reactive façades will offer opportunities to link the production of heat and high-quality biomass with the reduction of carbon emissions. Arup will continue to investigate the potential for using bioreactive façades on an urban scale, to create a new value chain and establish surplus energy and zero carbon building clusters for the future.

The system was developed by a multidisciplinary team of specialists in Berlin from materials consulting, product development, façade engineering, building physics, glass engineering, sustainability, ICT and MEP

Arup Design School
Powerhouse for collaborative innovation

Today, quality alone is unable to guarantee success in the challenging business environment. We shall be more innovative, collaborative and insightful.

Lying at the heart of our design culture, the Design School is an important part of Arup University's innovation training which aims to connect people and sharpen their design skills through debates, discussions, reflection and cooperation.

At these 3-day events, young professionals from different disciplines across offices get inspired by a series of talks and think beyond their own discipline to accomplish group exercises on a specific theme such as 'Brilliant Failure'. They are also given the opportunity to develop their soft skills such as presentation and communication. This cross-disciplinary thinking and working enable us to seek best design solutions and give us the edge in delivering added value for clients worldwide.

In East Asia, the Design School is organised twice a year. In the near future, it will be open to strategic partners to allow cross-fertilisation of ideas.

Arup University provides high standard training in technical knowledge, soft skills and innovative thinking and problem-solving, as part of the firm's strategy. The offerings range from hours-long classroom learning for day-to-day work to 1-year Master level programmes to equip Arup's future leaders in new business areas.

The InnoVision Lecture Series give our clients and the general public a fresh insight into the built environment

The biennial East Asia Design and Technical Excellence Awards recognise projects of outstanding quality and creativity within the region

Transforming enterprise knowledge into better solutions

Arup's Hong Kong office has recently been named as the 2015 Global Independent Operating Unit at the prestigious Most Admired Knowledge Enterprise (MAKE) Awards, following Arup Group's clinching of the Global MAKE Award winner in 2014.

Ranking among the world's best known corporations such as Facebook and Google demonstrates Arup's commitment to knowledge management and our ability to transform enterprise knowledge into tangible services and solutions.

From the creation of new ideas to sharing of knowledge and harvesting of best practice, effective knowledge management has enabled us to deliver the best of Arup globally to our clients.

Skills Networks (communities of practice) serve as the principal framework for our technical knowledge sharing. They are led by regional Skill Leaders who lead discussions on technical quality, and identify training and development needs for their fellows.

We also organise seminars, and produce in-depth publications and online videos to keep our staff and clients abreast of the latest technical development in the industry.

Quick facts:

- 46 Skills Networks representing 46 technical skill sets
- ~10 global skill forums every year to gather experts in different fields to share best practice and build up connections
- Technical lunch talks held almost every day in the Hong Kong office

Naeem Hussain: creating synthesis of design

"To me architecture and engineering are more or less the same thing. Our business is the built environment and we are basically designers who combine architecture and engineering in a holistic manner."

"I would rather be known as a designer of bridges, rather than as an engineer or architect," said Arup Fellow Naeem Hussain, who, with his background in both engineering and architecture, is well recognised for his expertise in combining form with function and commercial viability.

Looking back, it seems he was destined to the profession of building 'links', both bridging physical spaces and aesthetics, analyses and economics.

Early influencers

Naeem recalled it was his father, a civil engineer working on railway bridges, who had the most influence on him, exposing him to the beauty of problem-solving in the built environment. Consequently he became interested in buildings and wanted to be an architect but there were no architectural schools back then in Pakistan, so he studied engineering instead and later studied architecture in the UK.

Regrettably, engineering firms were skeptical when he tried to get back to engineering in 1969. "I tried all the mainstream consultants and contractors and they always asked me 'Why did you study architecture?' as if I had done something wrong." This continued until he met Jorgen Nissen, former Arup global bridge design leader, who actually showed great interest in his background and was interested in holistic design. "He offered me a job in Arup and became my mentor looking after me but with a very light touch," he said with deep appreciation.

Another pivotal person in his career was Mick Lewis, also an Arup legend, who instilled the importance of money at a time when the word was still a taboo for designers in Arup. "Mick gave me another perspective – without money, we can't do anything; and it made me aware of the necessity of having a healthy financial outcome of the projects that we undertake whilst doing a good design for the client," said Naeem.

Go where projects are

Now he has been in the industry for more than 50 years with his projects spread over 25 countries, from some of the world's largest infrastructure works to unique urban landmarks.

Naeem describes himself as having a 'wanderlust'. "Work is not going to come to you; you have to go where projects are," he suggested. In those early days, he worked in the UK, Hong Kong, Nigeria and Malaysia, working on projects and also growing bridge teams there.

Finally, he decided to settle down in Hong Kong some 18 years ago. The best thing about being in Hong Kong, he said, is: "I don't know what I will be doing this time next year – I have no clue but I know something will come along." He believes Hong Kong is still the centre for bridgeworks in this part of the world. From here, Naeem and his team are working globally, on projects in South Korea, Brunei, Malaysia, Thailand, the Philippines and even the UK, US and Canada.

Among all these projects, he picked the Forth Replacement Crossing as his best solution so far. It's currently being built in Edinburgh alongside the existing Suspension Road Bridge completed in 1964 and the Cantilever Railway Bridge completed in 1894.

"The key was to design a bridge that would be a visually sympathetic partner to the other two bridges without dominating them", he said, actually seeing it as a fantastic 'design opportunity'. The new crossing will be slim and neat, compatible with the landscape and complementary to the other bridges. This perfectly fits his criteria of a good design: "clean, uncluttered and fitting into the location".

'Diamond' rules

Naeem also shared his 'diamond rules' to deliver good design: "First of all, you should not have pre-conceived ideas; always try to start with a clean sheet." He urged designers to listen to the client and study all the 'data' including the client's budget before embarking on the design.

"We once had the attitude that we will always do a Rolls-Royce of a design, but maybe the client wants a China Geely! We have to tailor our design to meet the client's aspiration," he pointed out. "These days we can create any shape, but the point is: 'Is this what the local people want? Does it fit into the context?'"

Of course, design cannot be done in isolation. Naeem believes the best thing about Arup is that we always think and talk about ideas together, stimulate each other and come up with the best solution.

6-decade career in projects

© Alistair Scott/ Shutterstock

Shaw Theatre and Euston Library in London, a tall building back then

1960s

1970s

Bishopthorpe Bridge in York with its aesthetically pleasing curved soffit ; Benue Bridge in Numan which opened up the north-east of Nigeria

1980s

Ludgate Railway Works, London which opened the view of St. Paul's Cathedral by replacing the 1870s railway viaduct with an underground station and restored the railway link between the north and south of the Thames River

1990s

© Niels Poulsen

Øresund Link, Denmark-Sweden that took Arup into the consultants' league for big bridges

© John Nye

© Transport Scotland

2000s

Stonecutters Bridge, Hong Kong with its iconic mono-towers and a cable-stayed span in excess of 1,000m

Forth Replacement Crossing, Edinburgh, the world's longest 3-tower cable-stayed bridge with spans of 650m

2010s

Temburong Link, Brunei, a 30km landmark sea-crossing bridge with unique Islamic architectural towers

© Dissing + Weitling Arkitektfirma / Transport Scotland

Forth Replacement Crossing, Edinburgh

Never be constrained

Looking to the future, Naeem sounds even more excited speaking of new materials, emerging technologies and unstoppable urbanisation worldwide. "I wish I could start all over again, as I see there is going to be greater and better opportunities for design," he said, noting that composite materials will drive bridges to be even longer and much lighter.

"The key," he said, "is that we should do it more efficiently and use money more wisely. This again requires us to tailor solutions to locations and needs." This applies to projects of all sizes, from mega infrastructure to small community projects such as 'Bridges for Prosperity'. "We should use our ingenuity to help local people prosper," he said.

When asked about his 'secret' to stay passionate, he simply replied: working with younger people. "They are all eager to design and create, are well-educated and computer savvy, not constrained by 'this is the way we've done it in the past '; and that makes me enthusiastic."

Naeem has been in the industry long enough to see all the dramatic changes, and the biggest one is the undergoing digital revolution. While appreciating the beauty of all the digital tools, he warned that they are only aids and automation often leads to repetition. "Computers cannot design things for you; and without human ingenuity, there's no spark to life."

He encourages today's young designers to think beyond just analyses and to have broader knowledge of arts, sculptures, painting etc., which will help them think in 3D; and above all, not to do things by rote. "Don't fall into the trap of doing it as your colleagues did before; you must be able to think for yourself," he said.

5 things to watch: managing people and projects

1. Go back to what we really are – designers who manage people to deliver projects that make money.
2. Get things right first time, and do design reviews regularly. A reputation for technical excellence is hard to earn but easy to lose.
3. Try to find out what is bothering people and address the issues, this applies to co-workers and clients, and problems could be personal or work-related.
4. Let people feel they are the most special. Everyone is different and unique, and the key to getting the best out of someone is to respect and nurture their ability.
5. Flatten the hierarchy – everyone has ideas so make sure everyone has a say, no matter what their position is.

MingChun Luo: the scholar engineer

"The beauty of working for a small discipline at Arup is that we can be part of any big project – from the tallest to the largest, from the wildest to the most complicated," says Dr. MingChun Luo, former East Asia fire team leader and a well-respected name in the industry.

His work spans the region including all the high-profile ones, though many may not be aware of the involvement of fire engineers. "I'm probably the only Arupian that worked on all our Beijing Olympic projects – Bird's Nest, Water Cube, CCTV building, Beijing Airport Terminal 3, the less known Fencing Hall and Beijing South Railway Station!" said MingChun with pride and a sense of satisfaction.

Interestingly enough, the expert in fire engineering slid into the career largely 'by accident'. If he had not come to Arup, we would have probably still heard of him – in a parallel universe, Dr. Luo is a PhD supervisor who has published widely or an inventor in the sugar processing industry where he re-engineered the process of bagasse fired boiler.

Becoming Ir. Dr. Luo

Looking back, this seems a journey full of ordeals and blessings. The first critical moment in his life and career, MingChun recalled, was the restoration of Gaokao (China's college entrance exam) in 1977 after he had been farming for nearly two years following high school. He felt extremely lucky: "Otherwise I could still be in some remote area of the Mainland today." When this tumultuous period ended makes little difference in history, but the timing changed the fate of many individuals, he said, lost in time and thought.

Another U-turn signaled when he started working in a local yogurt factory following a Bachelor's degree in sugarcane processing and a Master's specialising in energy efficiency for drying bagasse before feeding into a boiler. This time he obtained a scholarship to study a PhD in Australia taking a close look at the bagasse combustion process in boilers and afterwards he joined a research initiative, part of Australia's Fire Code Reform research programme, as a post-doctorate for building fire simulation.

However, when everything pointed him towards a career in academia, after six years his research project ran out of funding and the scientist looked to industry for a new start. At that time, both Arup's Melbourne and Hong Kong offices had vacancies and MingChun chose Hong Kong "simply because it's closer to home".

"Fortunately, Hong Kong and the whole Greater China region has become the most exciting part of the world for fire engineering in the past two decades," said MingChun, "and Arup gives me all the freedom and opportunities to try new ideas and test new approaches."

All connected

No doubt, MingChun is a 'latecomer' to the industry – almost at the age of 40 when he joined Arup, but he is a strong believer of "no experience is ever wasted" – when all the dots are connected, you end up where you are supposed to be.

"As I always tell our young engineers, university graduates can handle 99% of our daily work, but the remaining 1% requires further training and thinking, and this makes all the difference," he said.

His research background has enabled him and his team to design tests and devise and justify cost-effective fire safety strategies for a wide range of projects, getting approval from the authorities. These include the natural smoke control system for Sands Macao, lift evacuation strategies for China's tallest buildings, and fire separation zones for Kunming International Airport which has recently won the Tien Yow Jeme Prize, the top honour for engineering and technology in China.

The list went on and on and MingChun became increasingly talkative and enthusiastic when reflecting upon all the bittersweet moments involved.

Today he still makes a 'hobby' of writing papers and so far has more than 100 published. He completed most of them over weekends or on holidays and he still remembers the good old days when he wrote by the pool after taking his daughter to swimming class.

"Writing papers improves one's capabilities in various ways: clear thinking, critical analysis, deductive reasoning, logical argument…" He highly encourages young engineers to write papers and present findings at conferences: "It's also one of the most effective ways of marketing." He said that Arup has already derived a number of opportunities from this, including the works of smoke plume models for Hong Kong MTR and the smoke control regulation for the new China fire code effective 1 May 2015.

Decoding the future

MingChun believes that the future of fire engineering lies in how Arup can influence the development of codes.

The most significant revolution in fire engineering over the past decades, he notes, is allowing performance-based design (PBD) outside of code requirements enabling very large and complicated developments. "However" he pointed out, "this also makes many people think that fire engineering is all about PBD without compliance with codes; actually, we need creative solutions both within and beyond codes."

1

3 ©Ben McMillan

2

4 ©Integrated Design Associates Ltd

Career in projects

Most exciting:

1 Duty-free shop at Hong Kong International Airport

The design team cheered and enjoyed all the wine after Arup's fire test demonstrated that the wine bottles in the Duty-free shop was within acceptable quantities of fire load.

Most challenging:

2 Sands Macao

The authority wanted to change the natural smoke control system on the roof into a mechanical one after the structure topped out. The Arup design team conducted all the analysis, justified our design and finally persuaded the authorities. This ensured the scheduled opening of the resort.

Most unusual:

3 Parkview Green FangCaoDi, Beijing

Working with four high-rise buildings inside a large glazed envelope, Arup developed a fire safety strategy that included an evacuation strategy and smoke extraction system. This was the first project in China to adopt a comprehensive fire engineering approach setting a model for fire engineering design in the country.

Most unnoticed:

4 Fencing Hall/National Convention Centre, Beijing Olympics

Among all the Beijing Olympic projects, this is the most complicated in terms of fire engineering due to its multiple functions during and after the event, but it fades into obscurity due to the more stunning structures nearby such as the Bird's Nest and Water Cube.

■ Kunming Changshui International Airport

©Zhou Ruogu Architecture Photography

Another fact is that many alternatives gradually become part of the code. When buildings are becoming taller and taller, larger and larger and stranger and stranger, they push the limits of codes as well as possibilities in engineering design.

"Arup has global influence and we are able to have a positive impact on the code development. Then we are in a better position to help interpret the code, give the reason behind and propose the alternatives," he said with confidence.

Humble tips

When asked about his advice to young people, he summarised in three Chinese phrases: 誠實 (straight and honourable dealings) – the basis to establish trust with colleagues, partners and clients; 踏實 (down-to-earth effort) which helps you to get experience, boost confidence and develop your own networks; and 紮實 (solid technical knowledge) that empowers you to make breakthroughs at a critical stage.

"These qualities, dealing with ethics, attitude and skill, apply to be a good engineer and a respectable person as well. They are always important and will remain relevant in the future," he said.

He also encourages young engineers to look beyond their desktop. "You should go out to conferences, client meetings and other Arup offices. If you don't make yourself visible, how can chance find and favour you?"