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Issue 3 2017

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T • PARK
Hong Kong's avant-garde waste-to-energy plant

ARUP

Welcome

Around the world, cities are struggling to come to terms with the impact of ever-scarcer resources, growing populations and climate change. In this issue of FIRST, we take a close look at how we are exploring smart, sustainable solutions that align with our clients' commercial, environmental and social priorities in a period of unparalleled urbanisation.

One of our recent showcase projects is the T • PARK sludge facility in Hong Kong which provides an eco-friendly solution to the problem of sewage treatment facing the city. In Shanghai, we deployed a wide range of energy-saving strategies for The Hub which transforms Hongqiao into a vibrant, low-carbon business district. Not only do we do eco-friendly new build but we also innovate 'out of the box for a box' – offering a cost-effective alternative to retrofitting for the Kuzumi Electronics Laboratory.

At Arup, we believe that digital technology and data have a major role to play in finding new ways to meet today's challenges. Inside this issue, you will read about how we are using advanced digital tools to design the unique structure of (W)rapper Tower in Los Angeles and find out more about our in-house developed scripting and visualisation tool that integrates environmental analysis results into BIM applications for better building sustainability.

Also in this issue you will read the stories of Eric Chan and Timothy Suen, two technical leaders who are devoted to connecting people and places with better roads and railways. Meanwhile, Bruce Chong shares his experience as the first doctoral graduate supported by East Asia Arup University.

This issue also presents some of our recent foresight reports and research studies on topical issues ranging from the circular economy in the built environment to addressing the vulnerability of ageing populations.

We hope you enjoy reading this issue and find the content valuable.

FIRST is a publication produced by East Asia Arup University (AU) for our clients and partners, exploring design, innovation and technical solutions for the built environment. It takes its name from the unique model of AU: Foresight, Innovation, Research, Sharing, and Training.

For more information on any of the topics featured in this magazine, please contact us at ***ea.arupuniversity@arup.com****.*

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T • PARK

Hong Kong's avant-garde waste-to-energy plant

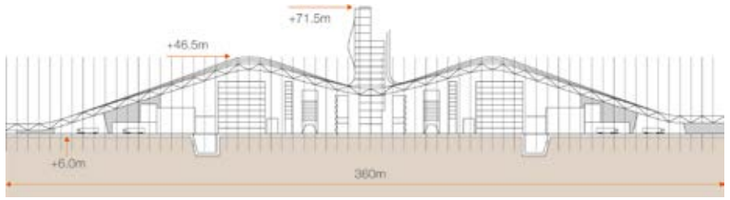
Hong Kong's first waste-to-energy plant, T • PARK, is the largest sludge incinerator and one of the most technologically advanced facilities of its kind in the world. 'T' stands for 'transformation. The facility signifies Hong Kong's dedication to transform waste into energy and has also transformed the public's perception of waste treatment by combining sludge processing with educational and ecological features and even spa services.

The facility incinerates the sludge — a thick mud-like by-product of sewage treatment — collected from 11 locations in Hong Kong, and at its peak can treat up to 2,000 tonnes of sludge every day. Utilising the advanced fluidised bed incineration technology, the foul wet sludge that would otherwise be dumped in a landfill will be reduced to ash with its original volume reduced by 90%, thereby substantially lessening the loading on landfills previously used for sludge disposal.

Client:
Veolia-Leighton-John Holland Joint Venture

Arup's scope of services:
Civil engineering, structural engineering, building services, energy strategy, process engineering, fire engineering, landfill gas assessment, water engineering, geotechnics, management consultancy

Selected awards:
Grand Award, Structural Excellence Awards 2016, Hong Kong Institution of Engineers & Institution of Structural Engineers Joint Structural Division
Merit Award - New Buildings category, Green Building Award 2016, Hong Kong Green Building Council



The plant fits exactly into the undulations of the roof

Working with the Veolia-Leighton-John Holland JV on the engineering-procurement-construction (EPC) contract, Arup has been involved in detailed engineering design for all civil, structural, geotechnical and building services associated with the buildings along with the mechanical and electrical engineering and fire engineering for the project.

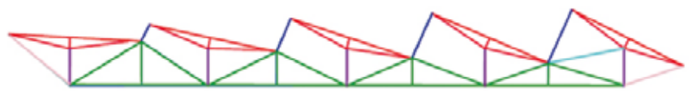
Erecting the structure

The streamlined wave-form design of T • PARK was inspired by the surrounding sea and hills. It also flows in response to the exact height and layout of every stage of the sludge reprocessing technology within, with the highest point accommodating the main incineration plant. The symmetrical layout houses two process plants that are exact mirrors of one another. The tall flue gas stacks are hidden away from view by integrating with the administration building at the centre.

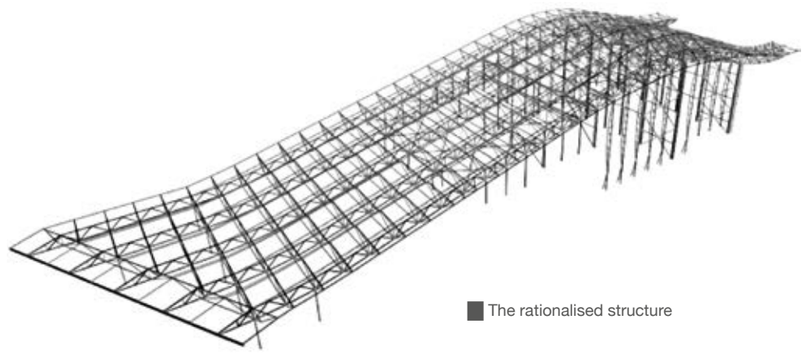
Achieving the dramatic architectural form of the 400m-long roof structure posed considerable design challenges. The original architectural geometry of the roof was a series of 3D twisting triangular trusses with no repetition, spanning longitudinally up to 50m and with a continuously varying cross-section to reflect the varied stepped profile in the transverse direction. However, the Arup team realised that the design could be rationalised, without compromising the overall architectural intent, by resolving the roof into a series of planar trusses and using the secondary transverse steelwork to form the variable height. As a result all components could be repeated, except the varying length of the secondary framing. This simple solution improved the buildability of the roof and also reduced fabrication effort and costs.

The Arup team also faced tough challenges regarding the foundations of the facility, as the site was previously used for disposal of pulverised fuel ash (PFA) from the adjacent power station and subsequently capped with general fill. A range of foundation solutions were assessed. Given the likelihood of ongoing settlement and the sensitivity of the process equipment and interconnection pipework between process facilities, piling was selected as the general foundation system. Driven H-piles were eventually determined to be the most appropriate solution because they could be installed quickly and mitigated the need to dispose of excavated PFA that would have been necessary for a bored pile approach, and would be sufficiently flexible to accommodate unforeseen ground conditions. To provide mitigation from corrosion the H-section piles were also designed with a 50-year corrosion allowance. Large concrete pile caps were then constructed on top of these piles, onto which the facility was built.

Architectural geometry – 3D twisting trusses



Structural geometry – Planar trusses & A-frames



The rationalised structure

Ensuring health and safety

To satisfy air quality standards and maintain a comfortable surrounding environment, deodorisation systems and flue gas treatment systems were adopted. At every stage of the process where sludge is potentially exposed to atmosphere the plant spaces are maintained at negative pressure and air emission is processed through a centralised de-odorisation system. The flue gas from the incineration process is also treated and monitored to ensure compliance with the European Waste Incineration Directive standards, one of the most stringent in the world.

As T • PARK combines industrial facilities with a visitor centre, it presents a unique challenge for fire safety design. In addition, the sludge treatment process involves high-temperature incineration that is new to Hong Kong. As a result, prescriptive fire codes cannot be applied fully to the facility to address the specific fire risks. Therefore, the Arup team conducted a fire risk assessment for the plant areas to demonstrate the proposed design on fire services installations, fire safety management measures and zoning to protect against explosive items. CFD studies on smoke extraction systems for the incineration halls and sludge treatment process were also performed and long travel distances in the plant were addressed by using timeline assessment. These assessments had enabled us to identify hazards and propose corresponding mitigation measures and to develop an overall fire strategy to address the life safety of the facility's users.

Sustainability

Arup's design has made T • PARK a showcase for sustainability. It is an entirely self-sufficient facility with no external supply of water or electricity and is designed to achieve the BEAM Plus Platinum rating. As the sludge burns, energy is conducted in the form of steam and reprocessed to power the entire facility. It will also export surplus power up to 2 megawatts to the regional power grid, providing enough electricity for up to 4,000 households. A 'zero effluent discharge' policy means wastewater is treated and reused for irrigation, flushing and cleaning purposes. Potable and processed water is supplied by processing sea water through a desalination plant that is capable of producing up to 600m³/day, while rainwater is collected for non-potable use.

T • PARK also incorporates numerous green features. For example, up to 70% of the facility is landscaped or has green roof coverage and it houses three spa pools at different temperatures using the waste heat energy recovered from the sludge incineration process. The building form was also optimised through collaboration with the architect and the Arup team and incorporates north-facing skylights to maximise the use of daylight.

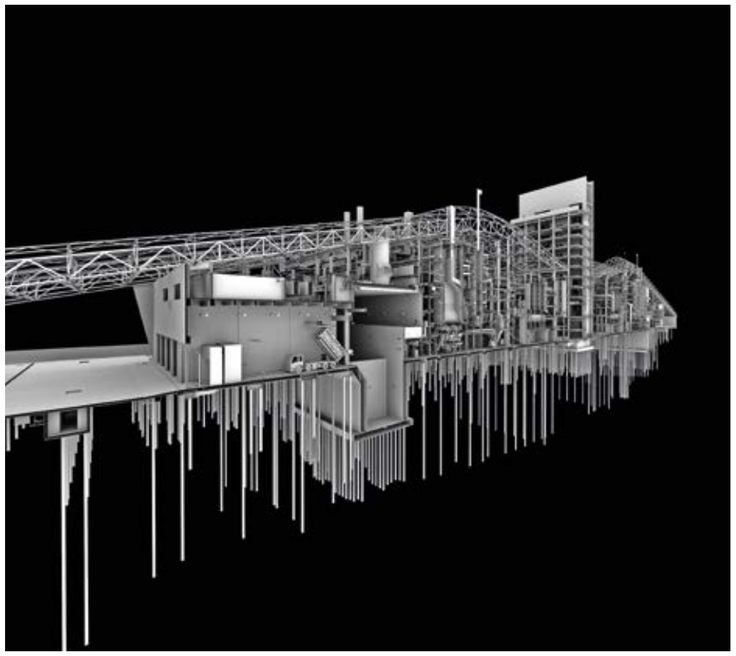
An optimum solution using BIM

Building Information Modelling (BIM) played a key role in the project. The entire design process followed a complex 3D BIM model which facilitated the design, analysis and coordination throughout the project. For example, the use of BIM helped the Arup team to visualise the relationship between the process equipment and the structural supports and to ensure more than 1,000 process pipelines around the site were properly routed and the equipment properly connected and accessible. With these invaluable visualisation and modelling tools the team could easily identify conflicts and resolve issues at every design stage, reducing queries and clashes during construction on site and allowing the project to be completed successfully within the tight 37-month construction programme.

Our 'total design' approach helped realise this unique facility which combines sludge treatment and power generation with educational and recreational facilities. T • PARK provides an innovative and eco-friendly solution for the problem of sewage sludge disposal, and demonstrates that industrial functions can be incorporated seamlessly into city lives.

© Marcel Lam Photography

Spa water is warmed by the heat from the incineration process



Sectional view of the facility through BIM model indicating integration of roof with process equipment

Client:
Shui On Land

Arup's scope of services:
Structural engineering, mechanical engineering, electrical engineering, public health engineering and building sustainability

Selected awards:
Best Mixed-use Development (Gold), MIPIM Asia Awards 2015

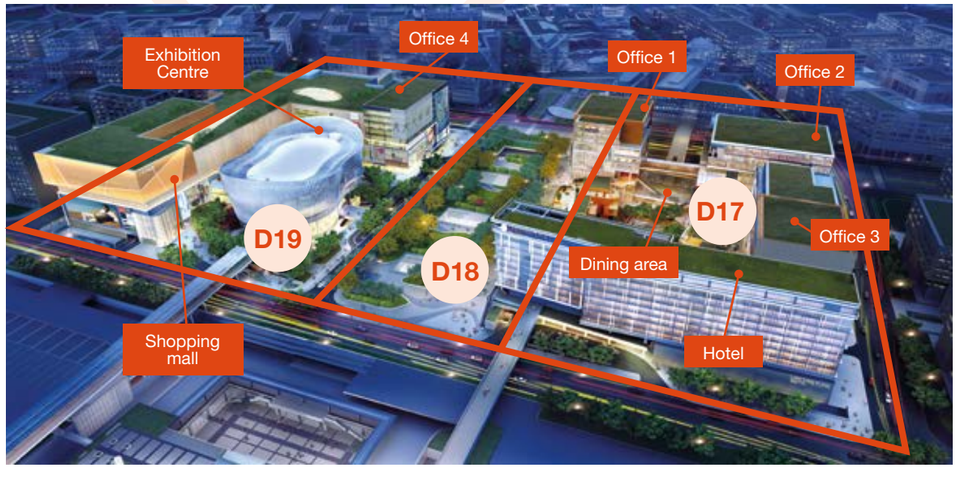
© Kingkay Architectural Photography

The Hub
A showcase of sustainable urban living

The Hub in downtown Shanghai features a range of sustainable solutions to help make Hongqiao Central Business District (CBD) a vibrant, low-carbon community.

A futuristic 'Starship' exhibition centre for art, culture and business events appears to 'float' at the CBD's heart surrounded by offices, hotels and malls. With immediate connection to domestic flights, metro lines and inter-city high-speed rail networks, the development serves as a real 'hub' for working, living and travelling as well as a gateway to China's prosperous Yangtze River Region.

In line with Hongqiao CBD's development strategy, the concept of low carbon and energy conservation was adopted from planning through to design and construction.



© P&T Group/Ben Wood Studio Shanghai

Shanghai's first low carbon business community with a total GFA of 390,000m²

Energy strategies

We deployed a wide range of energy-saving strategies including district cooling and heating supply from two energy centres that make use of the combined cooling, heating and power (CCHP) system to serve different land lots. The district supply system provides an efficient solution by taking the full advantage of economy of scale and the diversity in cooling and heating demand for different buildings.

As the Hub was the first sites of the Hongqiao CBD core zone to start construction, all the system interfaces, supply temperatures and incoming water pressure for the district system were carefully considered and co-ordinated with the energy company. To increase reliability, the external chilled water and hot water pipes are distributed via underground tunnels so that the pipework can be easily accessible for maintenance.

Linking with the services tunnels are individual heat exchange stations at the basement level of D17 and D19. The incoming district supply and return pipes are connected to the heat exchangers and the chilled/hot water is further distributed to the terminal units via the secondary circuit by retrieving the energy from the heat exchangers.

With this configuration, the cooling towers, chiller and boiler plants for individual buildings are no longer required. It has improved the building space use and has saved significant plantroom area — 70% less comparing with the conventional air conditioning system and hot water system. Noise, vibration, thermal plume and waste heat pollution have also been significantly reduced.

The removal of the rooftop cooling towers and chillers also provides greater flexibility to design the building envelope and maximise the greenery or accommodate functional areas on the rooftops.

Renewable energy systems have been adopted to further enhance the building performance. After comparing different systems such as wind turbines and geothermal heat pumps, a solar hot water system was installed in D17 & D19 offices and the exhibition centre to support more than 10% of the hot water supply. To balance the requirement for the refuge area as well as to maximise the roof greenery, the project team worked with the architect to tighten the installation space before finalising the overall scheme of solar hot water panels.

Water management

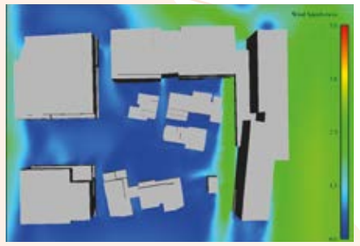
We also developed and implemented water harvesting and recycling systems to manage water consumption. Storm water from building roofs and AC condensate is collected and waste water is recycled. The recycled water, accounting for more than 40% of the development's total supply, is reused for flushing, cleaning and irrigation for the site after treatment.

Wind and thermal comfort

Arup's building physicists conducted extensive analysis to maximise daylight and natural ventilation reducing more energy-hungry mechanisms for keeping occupants comfortable.

Tri-generation CCHP System supply conditions:
Chilled water supply/return 5.5°C/13°C
Hot water supply/return 90-110°C/60°C
Water pressure 1.6-1.8MPa

District supply network and Energy Centres

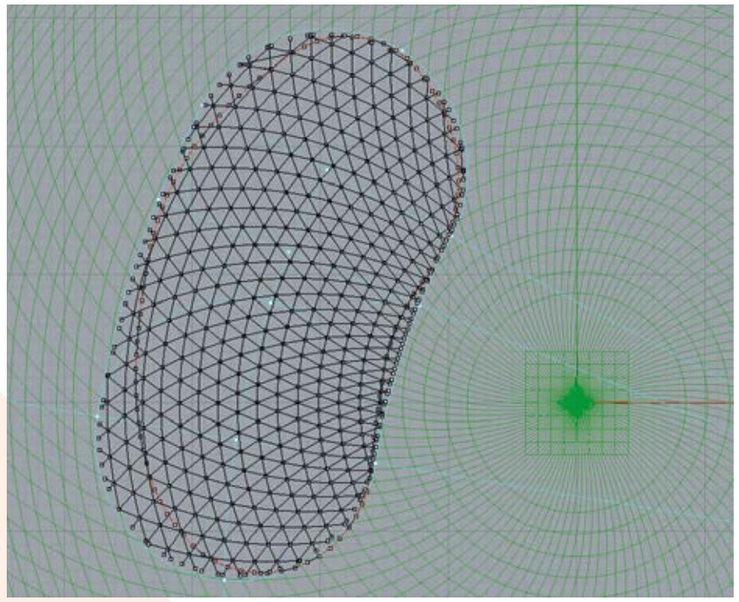


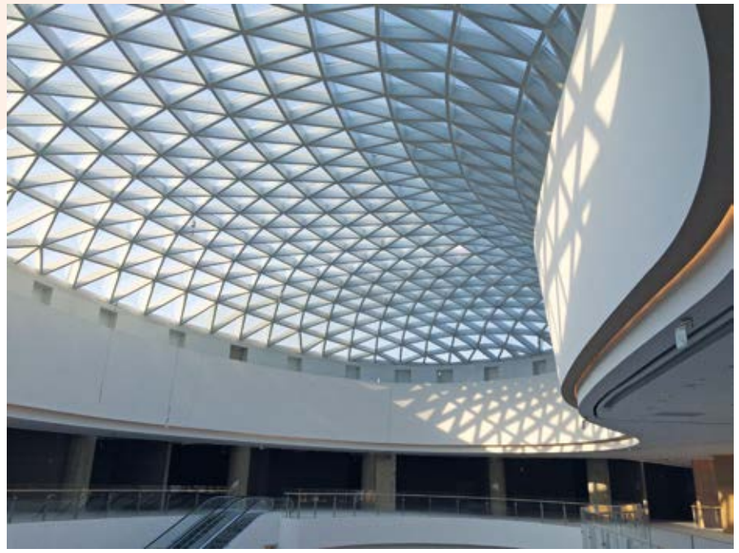
Outdoor wind analysis of the site

The team studied the indoor wind environment under natural ventilation and calculated the air exchange rate in the office buildings to ensure that the façade design meets the ventilation requirements. We also made recommendations on the number of operable windows and their locations, providing the most cost-effective solutions for the client.

To reduce solar gain, the team assessed the site itself, its climatic conditions as well as various external shading options with their impacts on building performance including horizontal fins, vertical fins, combinations of the two and opaque LED billboards. These studies ensured that the client can have confidence in the solutions proposed for the buildings.

CFD analysis was also conducted for different wind speeds and directions in all seasons to offer tailored solutions for pedestrian areas, keeping people comfortable when dining and enjoying themselves outdoors.





3D model by Grasshopper and the skylight after construction

Design it smart

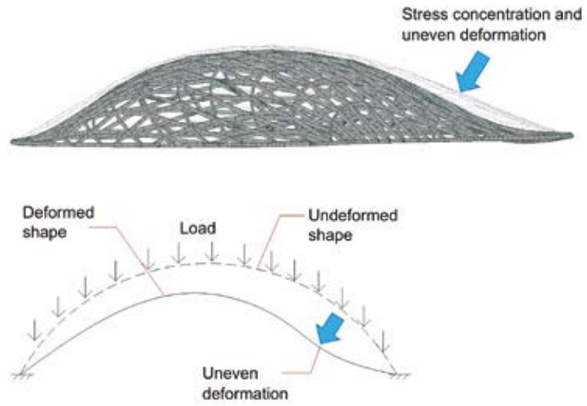
The project was on a fast-track programme which necessitated a compact design schedule. Arup engineers developed and adopted a number of advanced digital tools to explore the optimal structural solutions while keeping the project on track.

The mega mall features an irregular skylight of which the architect just had a concept idea with an outline. This gave structural engineers freedom to optimise the structural framing design while ensuring aesthetics. Using the 3D modelling tool Grasshopper, our structural engineers derived a shape of water wave interference in plan through parametric design to satisfy both structural and architectural requirements.

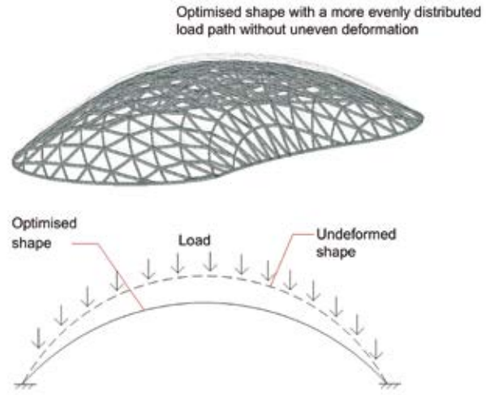
The skylight is a form-active structure which transfers its loads purely through axial or in-plane forces, with no bending occurs. Since the shape is determined by the loads and is not known in advance, a form finding process is required to determine the state of static equilibrium.

Using Grasshopper, a form finding analysis was carried out in the gravity direction to achieve an optimum form that makes the load path smoother without uneven deformation.

We also had to cope with the issue that a large number of piling works would start on site while the superstructure was still in the preliminary design stage. We used some design automation tools to enable the fast processing of pile construction drawings.



Deformed shape before form finding



Optimised shape after form finding

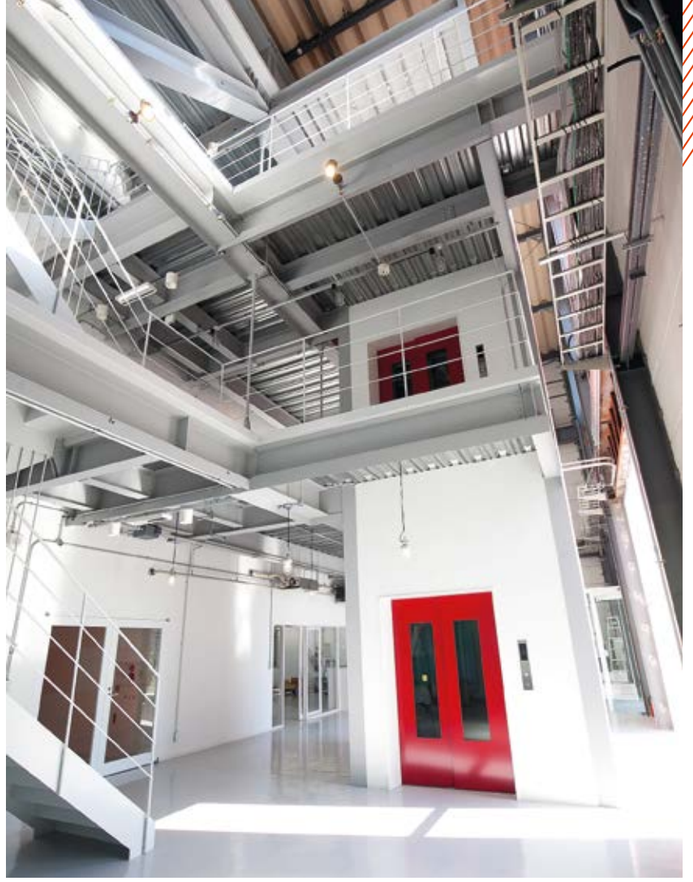
Traditionally, structural engineers design with excel spreadsheets or simple programmes and then pass the results to the drafting team for construction drawing preparation. In the Hub project, a one-step process was adopted from loading export from superstructures analysis model to detailed design calculation process and construction drawing production. This significantly sped up repetitive work induced by frequent design changes.

The automation based on Microsoft's Visual Studio link up all design software and drawings and help from automating design process to auto-reviewing construction drawings against the design criteria. Use of the design automation tools turned out to be one of the key factors for the successful delivery of this fast track project.

Opened in December 2015, the Hub has become a magnet for those who crave a new kind of urban living from all across the Yangtze River Delta and is setting a new benchmark for sustainable community design – over 50% of the whole development has achieved a China Green Building Label '3-star' rating with the rest obtaining '2-star' certification; and all the office buildings have achieved LEED Gold and Silver certification.

Client:
Yasui Masahiro Architects

Arup's scope of services:
Structural engineering, mechanical engineering, and lighting design



© ACP

The 'scrap and build' approach is commonly practiced in Japan, where many existing buildings are simply demolished and replaced with new ones. But when Kuzumi Electronics planned for a new office and laboratory to expand their capacity, they opted for an alternative: to reuse an existing factory they had acquired. This would be a sustainable solution that would also save time and cost.

Kuzumi Electronics Laboratory

Innovating out of the box for a box

Exterior and interior of the existing building

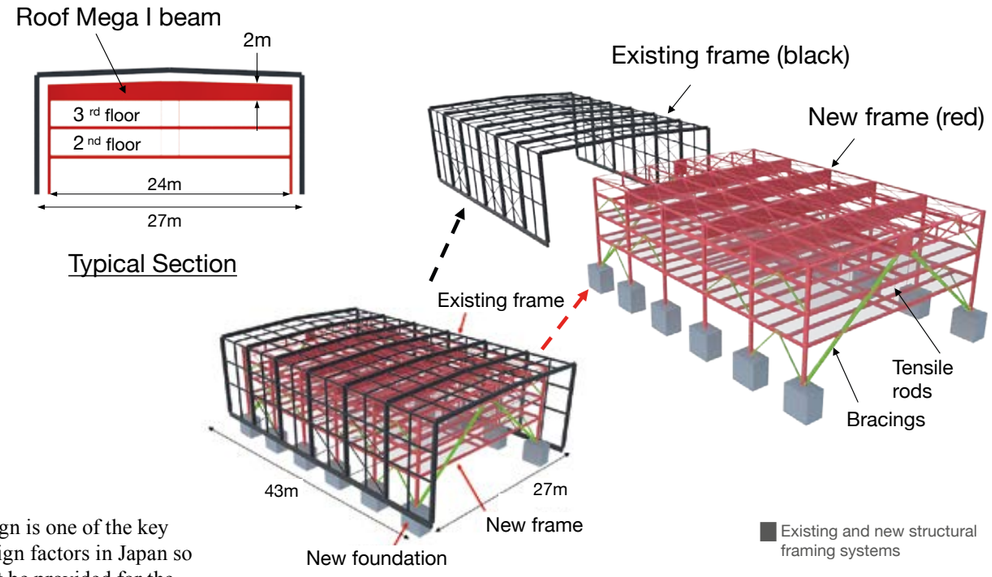
The existing factory was built 15 years ago using a steel frame and light weight concrete panels. The single storey building provides a huge 27m (w) x 43m (l) x 12m (h) space inside.

We were requested by the client to propose the most economical and innovative solution to effectively use the existing building, and to add two additional storeys to provide extra floor space for office use. The client would also like to reuse the existing building structure as much as possible and to have an open, column-less space on the ground level for efficient lab use and flexible adaptation to future needs.

Since the building was structurally sound with no serious damage to its structural elements and façade, we proposed that the entire existing building structure should remain unchanged. A new building frame would then be installed within the existing frame to provide the floor space required.

Putting another 'box' in

Our 'box within a box' solution comprised a mega 24m span steel truss system which would consist of mega I-beams 2m in height to form the roof of the new frame. The 2nd and 3rd floor slabs would be hung by tensile rods connecting to the mega I-beams so to eliminate intermediate columns on the ground level. With this solution we could effectively use the limited space inside the existing building and minimise the excavation to avoid damaging the existing footing foundations.



Existing and new structural framing systems

Seismic design is one of the key building design factors in Japan so bracing must be provided for the new structure to increase its stability against lateral loads. As there are no columns on the ground level, bracing along the outer wall of the new frame was the only option. We studied the brace locations carefully, considering foundation capacity, and ultimately derived a bracing arrangement that could resist the lateral loads with the minimum number of members.

Another major challenge in the project was the installation work of the new steel frame inside the existing building. The contractor would normally use a large mobile crane to install the long-span steel beam. However, the maximum height of the existing building was only 12m and would not be able to accommodate the crane. Therefore we worked out a feasible scheme with the contractor that involved removing the centre ceiling, so that the long-span beam could be installed without demolishing the existing façade and finishing.

As requested by the client, floors in the building would be flat, bare concrete. To minimise the deflection in the new steel frame when concrete was cast on the 2nd and 3rd floors, a pre-cambered truss frame was proposed and a pre-camber value of 30mm was determined by finite element analysis of the steel joints. The existing outer frame of the building was also examined and retrofitted to ensure that it would comply with the latest structural and fire regulations.

© Kawata-Kensetsu

Centre ceiling removed, and the 2nd and 3rd storey frames being hung from the truss

The retrofit resulted in a unique structure with a new extension encased in the existing building. Two floors have been added, increasing the total floor area from 1,000m² to 3,000m² and, similar to the ground floor level, the 2nd and 3rd floors do not have columns, only small tensile rods along the centre passageway.

A high-performance workplace

To make the building more suitable for office use, new window openings were provided to allow more natural lighting and fresh air, improving both the interior environment and use of electricity. In addition, an existing equipment pit about 15m in depth into the ground is now used as a geothermal heat exchanger to provide temperature control for the entrance lobby and the ground floor of the building.

Our innovative solution provides a cost-effective and sustainable alternative to the conventional 'scrap and build' approach and, as no demolition was required, the cost to retrofit the Kuzumi Electronics Laboratory is approximately 43% of the construction cost of a standard office in Japan. In addition there is a threefold increase in the total floor area but the cost of electricity has only increased by 15%.

This project will be an exemplar for building retrofit and there is great potential for Arup to market this sustainable and forward-thinking 'box within a box' solution to clients in Japan and other countries.

© ACP

The new extension provides huge column-free space

SCL C1103
Engineering an alternative solution

© Lands Department, HKSAR

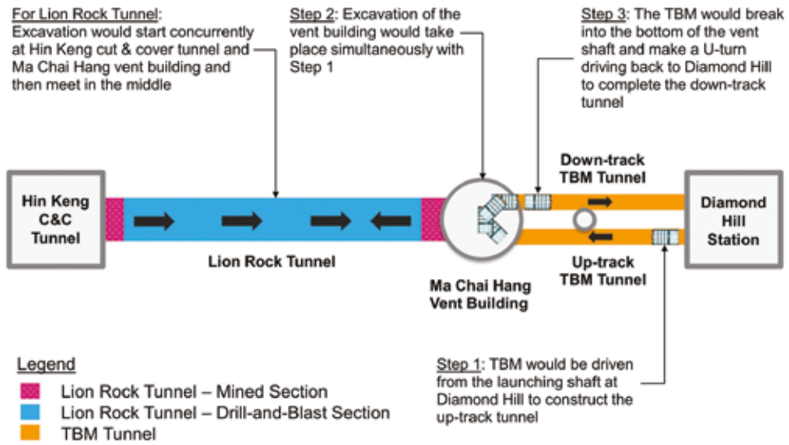
Client:
VINCI Construction Grands Projets

Arup's scope of services:
Alignment, architecture, civil engineering, structural engineering, geotechnics, tunnelling, building services, fire engineering, pedestrian planning, transport planning, hazard & risk, and building information modelling

Selected awards:
New Civil Engineer (NCE) Tunnelling Award 2016 - Highly Commended Project (£40m-£400m)

The MTR Shatin-to-Central Link (SCL) is a 17km strategic railway extension to enhance connectivity between districts in Hong Kong. Contract 1103 is one of the main civil works contracts and comprises 4km running tunnels from Hin Keng to Diamond Hill. Arup serves as the Contractor's Designer for VINCI Construction Grands Projets (VCGP), providing multidisciplinary detailed engineering design services for the tunnelling works and associated infrastructures.

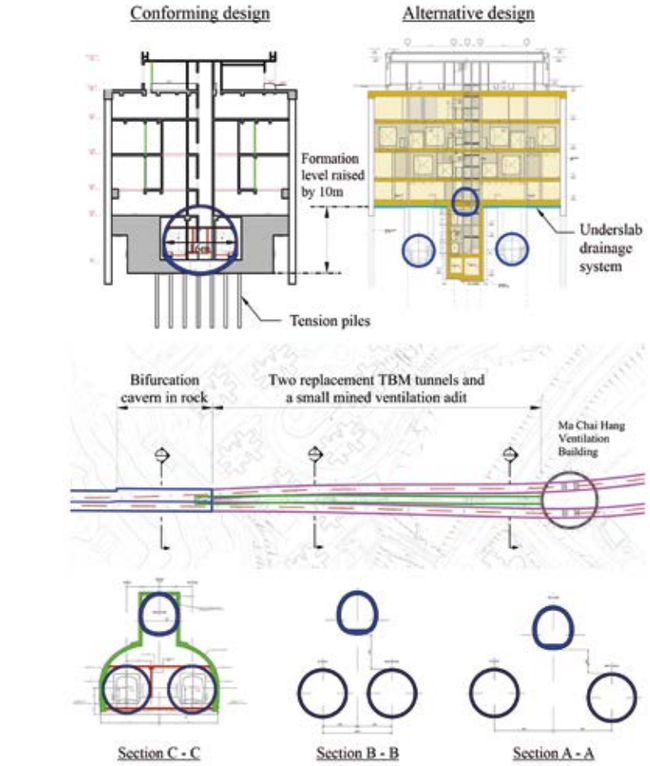
The tunnels traverse developed urban areas and the mountain range of Lion Rock and are divided into three sections to be constructed by different tunnelling methods: a 100m long cut and cover tunnel at Hin Keng; a 2.5km long single twin-track drill and blast tunnel at Lion Rock (with a short section of mined tunnel at each end), and 1.4km long single-track twin TBM tunnels between Ma Chai Hang and Diamond Hill. The works also include the construction of an underground ventilation building at Ma Chai Hang which is a 43m diameter circular shaft positioned above the tunnels.



Original work sequence

Challenging ground conditions

The conforming design led to several technical challenges. Firstly, the Lion Rock Tunnel requires a 250m long, 16m span section of mined tunnel from Ma Chai Hang ventilation building to be excavated in soft and mixed ground, posing a high risk to construction. This would be further exacerbated by the high groundwater level, requiring extensive grouting works to control water ingress to make the excavation safe and viable. Secondly, the existing residential buildings next to the ventilation building, which are founded on end bearing caissons on soils, may be impacted by ground settlement resulting from the tunnelling work.



Conforming design (large span mined tunnel) vs Alternative design (3 small replacement tunnels and underslab drainage system)

And thirdly, the 3D geological model indicated that the ground conditions of the ventilation building and the mined tunnel leading to Lion Rock was complex and it would be difficult to excavate the diaphragm wall panels through the corestone layer and into the hard rock.

Alternative design for the large span mined tunnel

In order to mitigate the risks associated with the mined tunnel excavation, Arup and VCGP collaborated to develop an alternative engineering solution to replace the large span mined section of Lion Rock Tunnel with three smaller tunnels. This involved the extension of two TBM tunnels beyond Ma Chai Hang ventilation building and the excavation of a small span mined adit running above and in parallel with the TBM tunnels for the purpose of ventilation. A bifurcation rock cavern was also designed to facilitate the transition from the TBM tunnels and ventilation adit to the drill and blast tunnel.

Underslab drainage system

Due to the relatively light weight of the underground ventilation building, flotation of the structure was a major design consideration. To cope with this challenge the conforming design used a thickened base slab to increase the deadweight of the structure, in combination with tension piles in rock to overcome the high uplift groundwater pressure. However, this would require the shaft to be over-excavated in order to accommodate the thickened slab.

Arup and VCGP devised an alternative solution by reconfiguring the conforming permanent structure and introducing an underslab drainage system below the base slab to relieve the uplift groundwater pressure, thereby eliminating the need for tension piles and thickened slab. As the formation level of the ventilation building has been raised by 10m, the excavation depth required has been reduced which minimised the extent of excavation through rock for the diaphragm wall panels. The two TBM tunnels could also run continuously between Diamond Hill and the Lion Rock Tunnel, thus delinking the TBM drives from the shaft excavation.

The underslab drainage system posed a challenge for this site due to possible settlement from soft ground conditions. To ensure the dewatering effects around the ventilation building would not adversely impact the existing buildings and structures nearby, a monitoring control protocol was developed to review the performance of the underslab drainage system throughout the entire period of construction of the ventilation building. And the monitoring records indicate that variations in the ground settlement caused by the dewatering process would not affect the existing buildings and structures.

Multi-fold values

The alternative design solutions developed by Arup and VCGP offer multiple benefits. The alternative design has made the underground structure easier and safer to build, resulting in construction programme certainty and enabling the contractor to submit a competitive tender offer.

From a safety perspective, the solution has eliminated the construction risks associated with large span mined tunnel excavation, reduced the risk of adverse ground movement to the buildings nearby and minimised the difficulties and time for constructing diaphragm walls into hard rock.

Furthermore with respect to the environmental impact, it has significantly reduced the volume of excavated materials (approximately 15,000m³) for the ventilation building and the Lion Rock Tunnel. And by eliminating the additional mass concrete and tension piles required in the conforming design to withstand buoyancy of the ventilation building, a carbon emission reduction of about 1,000 tonnes has been achieved. Building on the project's success, Arup and VCGP will be able to apply the design solutions to other new underground infrastructure projects in congested and well developed urban areas.

Client:
Samitaur Constructs

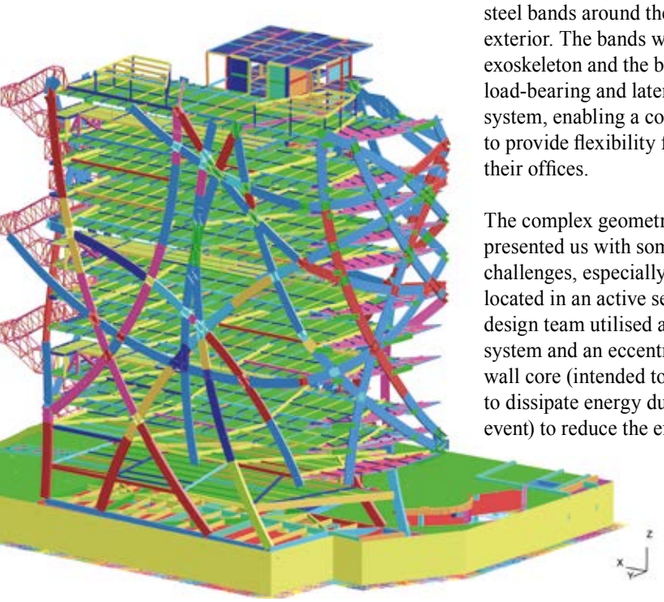
Arup's scope of services:
Structural engineering, civil engineering, mechanical engineering, electrical engineering, and public health engineering

(W)rapper Tower
Unwrapping the complexity

© Eric Owen Moss Architects

Rendering of the (W)rapper Tower

LS-DYNA model of the (W)rapper Tower



At 16 storeys and 73m tall, the (W)rapper Tower in Los Angeles features a unique design with curvilinear steel bands around the building exterior. The bands will act as a façade exoskeleton and the building's primary load-bearing and lateral load resisting system, enabling a column-free interior to provide flexibility for tenants to design their offices.

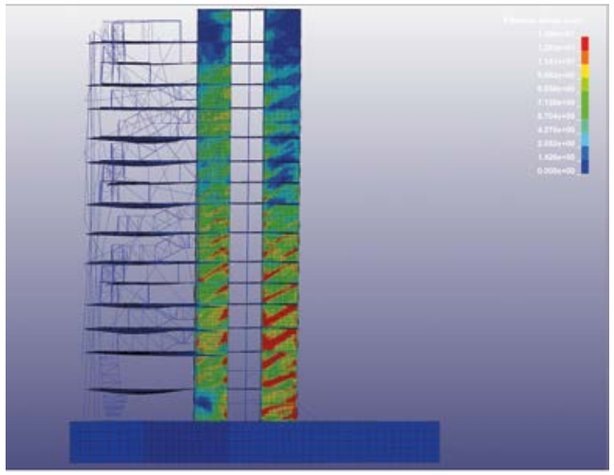
The complex geometry of the Tower presented us with some unique structural challenges, especially since the site is located in an active seismic zone. The design team utilised a base isolation system and an eccentric steel plate shear wall core (intended to yield and buckle to dissipate energy during a seismic event) to reduce the effects of peak seismic forces on the Tower. Also a performance-based design approach using Non-Linear Time History Analysis (NLTHA) was adopted to assess the behaviour and adequacy of this complex non-classified structural system.

Traditionally, NLTHA is only executed during the late stages of the design process due to the long time required for the complex model, data management and intensive computation. However, this requires the design team to make initial estimates of seismic demands using less complex linear analysis which might result in overly conservative design assumptions. NLTHA can later reveal unanticipated structural demands when the final design is fully analysed.

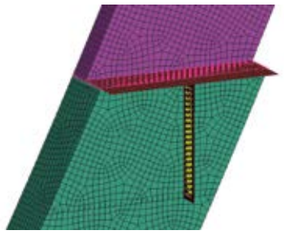
Due to the complex geometry and seismic requirements of the (W)rapper Tower, non-linear time history analysis in LS-DYNA was used as a design tool throughout the design process. We developed an efficient parametric and database-centric workflow to facilitate the analysis workflow.

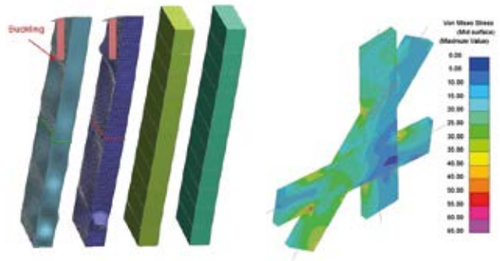
Building on our experience and success in past projects, this workflow allowed data which otherwise would be locked in disparate data sources to be liberated and transferred across different analysis (ETABS, SAP, LS-DYNA, Strand7), visualisation (web, Rhino-Grasshopper) and Building Information Modelling (REVIT, TEKLA) environments, enabling various disciplines in the Arup team to fully concentrate on their individual design while working together with a consistent set of data. The database-centric workflow also enabled the team to use different software freely and select the best tool for each design scenario. For example, floor framing was designed using ETABS while the lateral analysis under different earthquake conditions was evaluated in LS-DYNA. A smooth transfer of design data through the iterations between the two software platforms allowed the models to stay in sync throughout the design process.

The workflow also took advantage of cloud computing. Through the use of Penguin Computing and a scalable database on Amazon Web Services,



Explicit modelling of steel plate shear wall



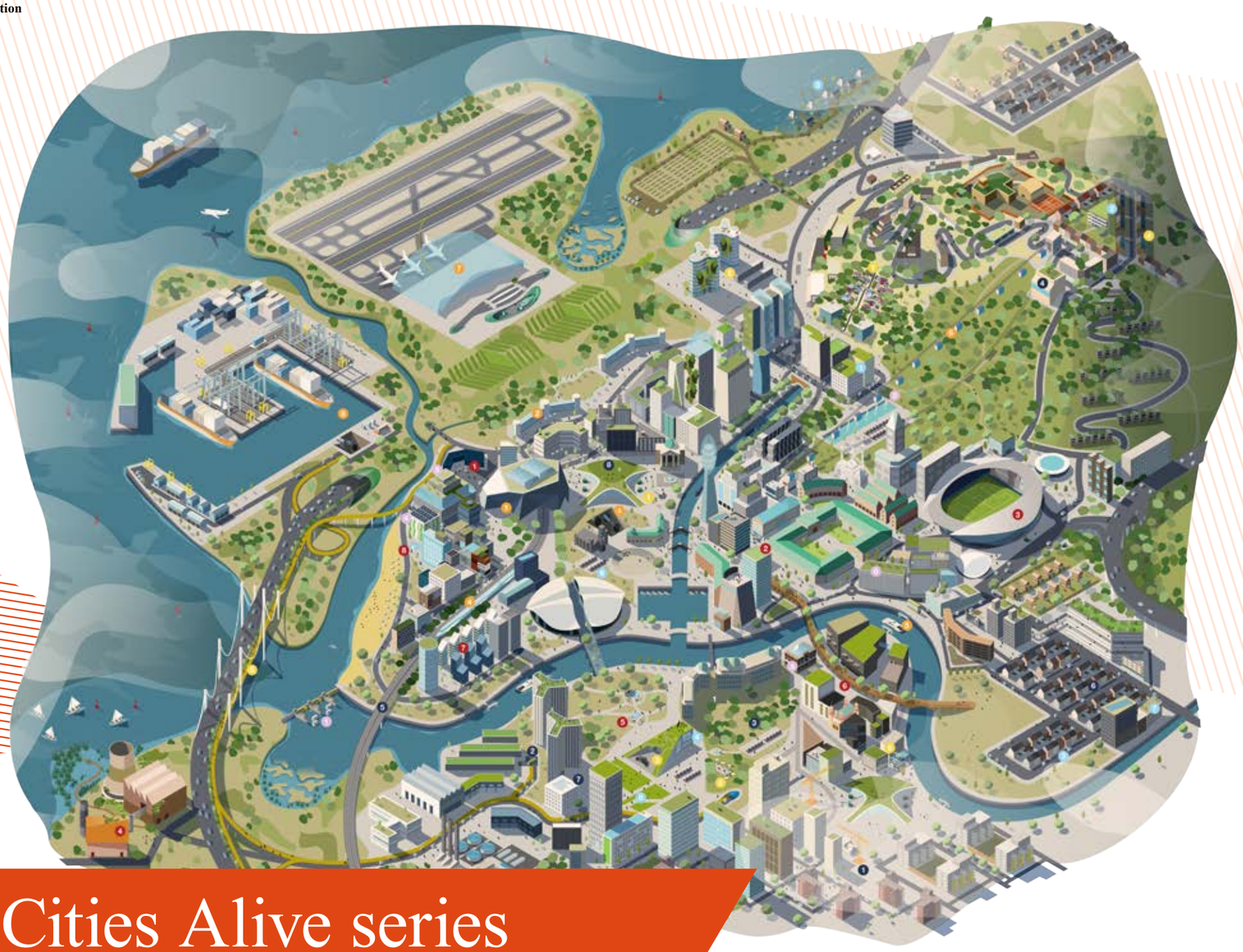


Non-linear analysis to determine the yielding point of the structural elements

the Arup team was able to deploy custom automated post processing on the massive amount of results data and significantly accelerated the process by shortening the analysis cycle from two weeks to two days. Furthermore, the Arup team was able to analyse the results in a more robust, visual and complete manner. For example, an explicit model of the steel plate shear walls were created to accurately capture their response during a seismic event. The Tower was also evaluated against different bounding conditions at different earthquake return periods using 63 individual NLTHA in each design iteration to envelop the structural loads. Developing a smooth parametric workflow from model generation, computation to post processing, facilitated executing this complex workflow in a cost-effective manner.

By facilitating the design workflow and through structural modifications verified by extensive analysis, Arup was able to deliver this vastly complex project with a savings in construction cost of over 20 million US dollars. The (W)rapper Tower will also achieve the highest Los Angeles City Resilience Rating for a building structure.

By advancing tools and capabilities developed on previous projects and proposing new strategies for mitigating traditional roadblocks, Arup provided a cost efficient structural solution that exceeds the code minimum safety requirements to realise the architect's vision for this unique Tower structure and paradigm in office building design.



Cities Alive series
Stories of a Future City

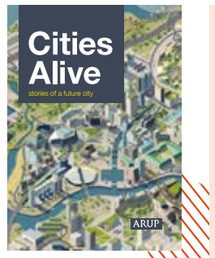
The Arup Foresight team has launched a new publication, Stories of a Future City, as part of the Cities Alive series, which takes a human-centred approach to rethinking how we should design and manage cities in the future.

This publication is a culmination of the Foresight team research and a special workshop conducted in London last year. It explores possible solutions and approaches to some of the most pressing challenges facing our cities, including the need for more resilient and adaptive infrastructure, the integration of autonomous vehicles, and the need for healthier and greener urban environments.

The publication showcases 46 elements spanning six categories: resources (e.g. urban farming), connectivity (e.g. automated public transit), processes (e.g. city dashboard), spaces (e.g. eco-remediation), community (e.g.24-hour park) and governance (e.g. mixed-use districts).

The illustrated elements allow us to imagine what a plausible future could look like on both city and human scale. Which solutions would be more or less desirable in our own communities are also discussed. The elements can help facilitate conversations and enhance understanding, and sharing visions of the future can act as a catalyst for agreeing priorities and developing tangible actions.

The project will continue to explore these elements in play within more specific narrative frameworks such as the Circular Economy.



Exploring the future city development of Hong Kong

Organised by the Hong Kong Institution of Civil Engineers, the workshop used these 46 elements to explore the future development of Hong Kong. Divided into seven groups, the 60 participants were encouraged to select the top three issues facing Hong Kong today, based on which they developed ideas for its better development and made evaluations of each idea. The key issues identified included aging population, urban regeneration, digital life, developing urban farming and underground streets and these were viewed as top priorities for the city's future development.

© Daniel Imade

The Circular Building

The built environment
From linear to circular

The engineering and construction industry is the world's largest consumer of raw materials. It accounts for 50% of global steel production and consumes more than 3bn tonnes of raw materials, making a huge impact on the environment. The increasing population is putting unprecedented pressure on natural resources and, therefore, a circular approach is recommended for the built environment.

More information of the Circular Building can be found at **http://circularbuilding.arup.com/.**

The circular economy concept aims to decouple economic growth from resource consumption. Instead of the traditional linear take-make-use-dispose model, products and assets are designed and built to be more durable and able to be repaired, refurbished, reused and disassembled. Maintaining components and their materials at their highest value for as long as feasible helps to reduce the environmental footprint and avoid rising costs, delays, and other consequences of volatile commodity markets.

Circular Building: an exploration

The Circular Building showcased at the London Design Festival 2016 is a good example of how the industry can work towards zero waste. Developed jointly by Arup, Frener & Reifer, BAM Construction and The Built Environment Trust in the UK, the Circular Building was designed for all the elements to be dis-assembled and re-used.

The full-scale prototype was intelligently designed and constructed with materials that can be removed with minimum damage, helping each component to retain its value. Digital technology was used to 'tag' all items, including everything from window frames to individual fixings, each with a unique QR code containing information allowing it to be reused.

Research into principles

To develop a circular economy in the built environment, a dedicated roadmap or framework is needed, together with a set of guiding principles for the design, engineering and construction sector. This will need to focus both on the economic business case and the opportunities to develop new ways to design and deliver projects. Such a framework would also help to drive innovation opportunities across the industry.

At Arup, we have committed to carrying out the following five actions:

1) To define effective circular economy design principles for our industry;
2) To co-develop and share research that can challenge our industry to apply circular economy principles;
3) To develop projects and enable prototyping with our partners;
4) To help educate our sector through learning programmes;
5) To work with others to articulate the shared values and mutual gains relevant to academia, government, corporations and individuals;

In the recent Arup report 'The Circular Economy in the Built Environment', we outline key principles of the circular economy, using the Ellen MacArthur Foundation's ReSOLVE framework (Regenerate, Share, Optimise, Loop, Virtualise, Exchange) to explore and contextualise practical applications in the built environment.

© Colt/Arup/SCC

SolarLeaf's bio-reactive façade generates renewable energy from algal biomass and solar thermal heat

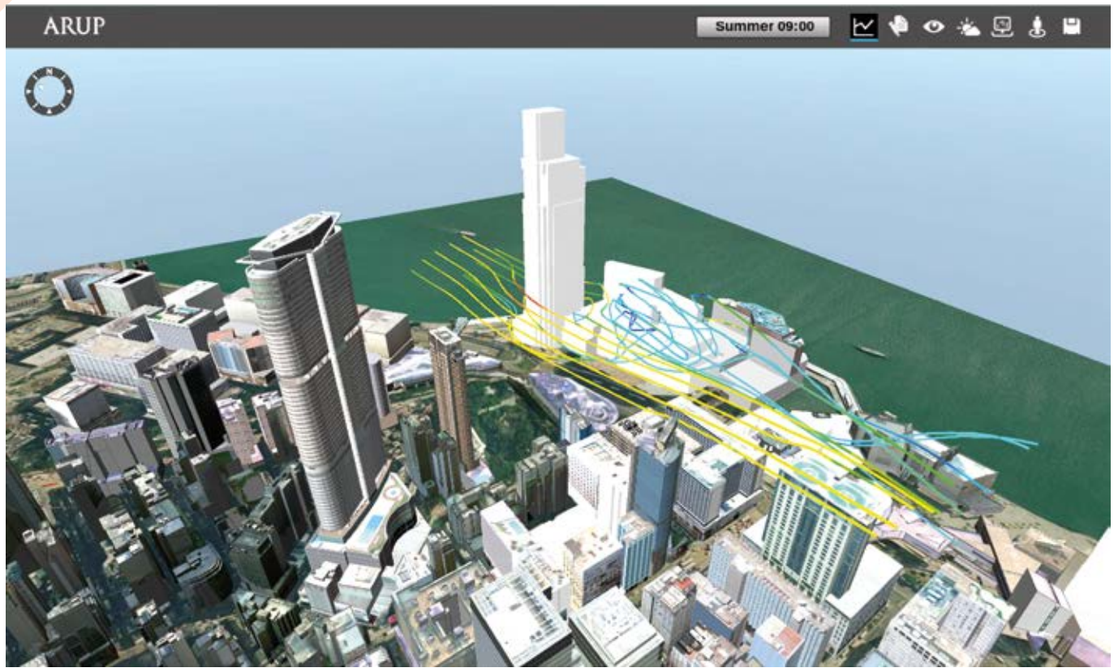
We identify how the circular economy can benefit Arup, our clients and the built environment sector and we reflect on the economic, social and environmental advantages of employing circular principles. Furthermore, we propose strategies to progress our offering, deliver new services, engage a wider network of stakeholders and unlock opportunities for all parties in the value chain, and consider how circular economy practices can be scaled up from the individual component or asset level for city, regional and even global economies.

Scan to download

We welcome partners and organisations to join us to promote and implement circular economy opportunities in the built environment and beyond. Please contact us at **ea.arupuniversity@arup.com** for more information.

Additive manufacturing technology, also known as 3D printing, can reduce material use when manufacturing bespoke building elements

BEM + BIM
for better building sustainability



Wind analysis

With the advent of digital transformation, data gathered from building designs is being put onto a common platform called building information modelling (BIM). Even though BIM is becoming increasingly popular in the industry, the commonly used data are mostly related to basic design properties like dimensions, whereas sustainability, environmental design and building physics are not yet incorporated.

A much needed tool

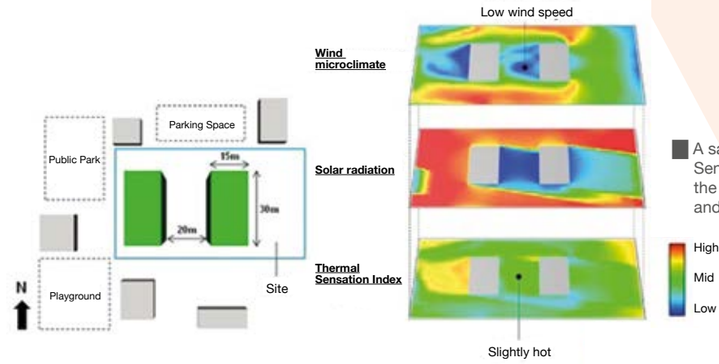
Building physics and environmental design are important factors in architecture due to the growing demand for high-quality sustainable buildings. Conventionally, separate analysis and modelling are performed for various aspects of the environmental design which reduces the efficiency of information exchange between the architect and engineers and impacts the quality of the design solution.

To address this, Arup has developed a parametric design approach, called Built Environment Modelling (BEM), which integrates multiple environmental factors, including air movement, natural lighting and solar heat gain, into a single medium. This allows engineers to explore the effects of different environmental design options efficiently in order to provide cost effective and sustainable solutions through passive design, renewable technology and energy efficient equipment.

However, this BEM analysis technique still has several problems. Although BIM is increasingly being adopted in projects for better project management, coordination and record, the BIM software currently available in the market is unable to interact efficiently with the environmental/BEM results. Also, since various environmental factors have to be simulated by different software and the output files are in different formats, integrating the results is often a long and complex process. And only the corresponding building physics engineers are able to extract the analysis findings for further investigation.

To cope with these needs, a research team in Arup's Hong Kong office has developed a scripting analysis tool to help decode BEM analysis results in different formats and then integrate them in a single visualisation platform. The result is a simple, user-friendly platform adopting a 'gamification' concept to engage users and help them explore the environmental performance of the built environment.

The interactive, SimCity-like gaming platform comprises real-life features, such as GIS data and city models, and users can navigate the 3D model to view the building design from different perspectives and select different environmental factors to 'experience' the effects.



A sample microclimate study. The Thermal Sensation Index is simulated by combining the effects from wind speed, solar heat gain and ambient air temperature.

Two case studies

Two case studies were conducted to evaluate the application of the visualisation tool in outdoor and indoor environments. The first case study on the New World Centre project in Hong Kong (a harbour-front site with a new tower, several mid-rise buildings and a park) incorporated building physics parameters, including sun path, solar heat gain and wind at various periods of time, to assess the impact on outdoor microclimate.

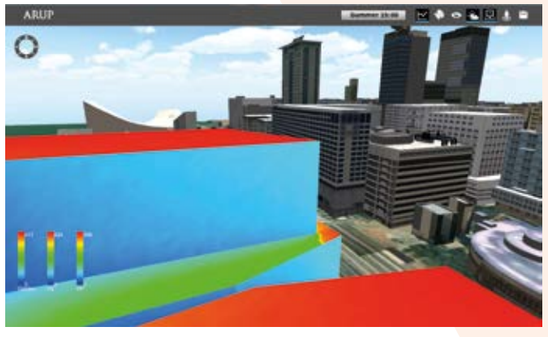
In the second case study, the indoor environment of the East Kowloon Cultural Centre atrium in Hong Kong was assessed based on building sustainability data (temperature and air velocity) as well as fire engineering data (carbon monoxide volume fraction, soot visibility, temperature and velocity). The results allowed Arup engineers to better investigate the indoor environment based on multi-discipline BEM factors and provide optimal solutions for both normal and emergency situations.

Multiple benefits

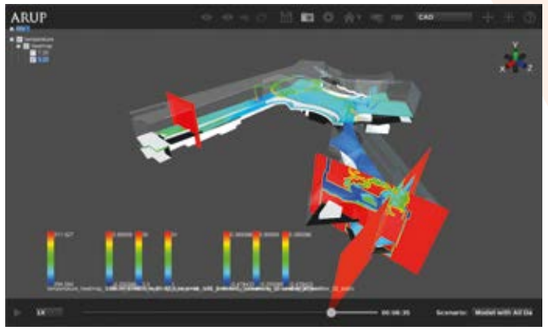
The new scripting and visualisation tool will help improve design team coordination and enhance better understanding and communications between disciplines.

In addition, as the results are saved as standalone executable files, they can be run on any computer. This mobile solution can be taken to design workshops and allows clients, architects and design teams to easily visualise the various design options and their impacts. The tool also features a 'comment and edit' function which allows the users to directly record the design input while playing, enabling real-time coordination and diagnostic with the project team on screen. The standalone BEM result file can also serve as a record for the client and property management team for future reference.

Furthermore, the tool helps to increase productivity through streamlining the post-processing work on multiple types of BEM result files. Thus a two-tiered design approach can be provided: detailed analysis and visualisation will still use specialised software for analysis and post-processing, while simpler visualisation analysis results can be exported directly to the tool, thus saving time and effort when only a simple model is required for checking and for design concept presentation.



First person view at the roof garden experiencing solar heat distribution



Visualisation of velocity streamline, temperature and soot visibility heat map simultaneously

The way forward

For the next stage, the research team is planning to expand the capability of the original scripting and visualisation tool to include BEM results from more disciplines. The team is also planning to explore the transition between outdoor and indoor environment, incorporate augmented reality and virtual reality and develop a script that can automatically read BEM result files and can be applied to all projects.

With the increasing adoption of the building environmental performance parameter in BIM, our BEM result scripting and visualisation tool will expand the capacity of two-way interfacing between BIM and BEM. This will increase focus on building physics factors and enhance design team coordination to provide integrated and cost effective environmental design solutions.

SHARPER

Seasonal Health and Resilience for Ageing Urban Populations and Environments

Climate change is already affecting major cities around the world in the form of extreme weather events such as heat waves and floods which are projected to increase both in frequency and severity in the future. These extreme weather events are not only resulting in damage, disruption and financial loss but also have significant implications for human health and wellbeing.

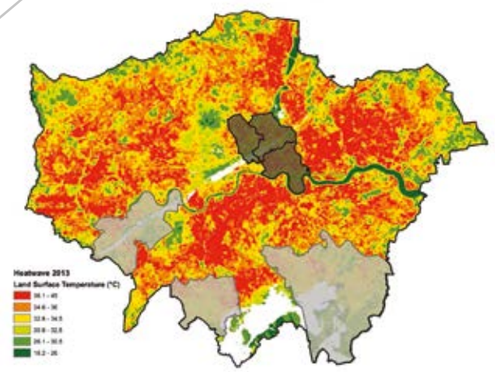
Currently 54% of the total world population live in cities compared to 34% in 1960. Alongside this continued urbanisation the world population is ageing rapidly: people aged 65 and older are expected to make up 22% of the total world population by 2050. These combined trends mean that more people will become increasingly exposed and vulnerable to climate change impacts.

To explore how these trends will affect the future of global cities, Arup conducted a two-year research study in 2014 entitled 'Seasonal Health and Resilience for Ageing Urban Populations and Environments' (SHARPER). The study, funded by the Arup Global Research Challenge and the UK Natural Environment Research Council (NERC), examines how increasing climate change impacts and continued urbanisation are affecting ageing populations in London, New York and Shanghai.

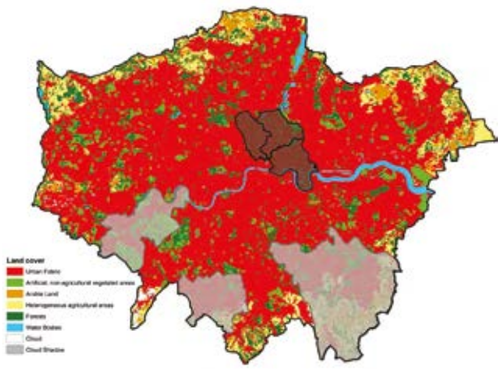
Exposure and vulnerability are assessed using a range of spatial, temporal and socio-economic data about climate related hazards, city characteristics and people. For example, satellite data was used to obtain land surface temperature maps which illustrated how temperatures could vary across a city due to the Urban Heat Island effect. Results showed that temperatures in different boroughs in London could differ by as much as 10°C during a heat wave.

Satellite imagery also showed that the built up area in Shanghai has almost doubled from 2000 to 2015, while agricultural land, forest and wetland areas have decreased significantly. This rapid urbanisation is exacerbating the effects of heat waves. In addition, in combination with more frequent heat waves, air pollution episodes in Shanghai could become more frequent and acute under the projected future climate.

A new Heat Vulnerability Index (HVI) was developed for London by combining census data with risk factors including high population density, a greater population of elderly with health and mobility issues and poor quality housing. Combining data for land surface temperatures and land cover with the HVI and data about the distribution of healthcare facilities, climate-related risk 'hotspots' in a city can be identified. Strategic and operational measures to reduce climate-related risks and increase resilience should then be prioritised for these areas.



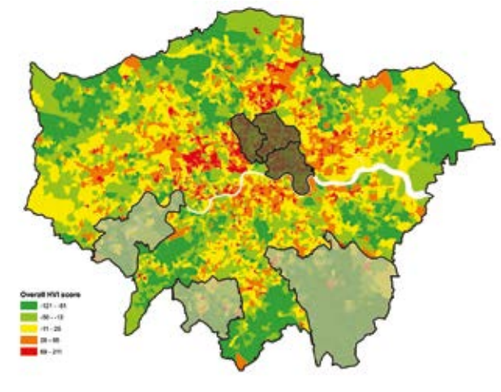
(a.) Land surface temperature data during a heat wave in London



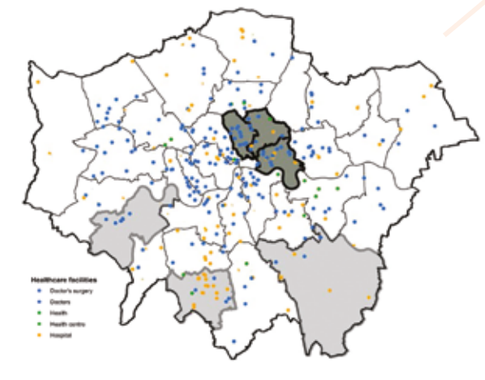
(b.) Land cover data for London

Map © Satellite Applications Catapult Ltd 2016; Data © NASA & USGS

Map © Satellite Applications Catapult Ltd 2016; Data © NASA & USGS



(c.) Heat Vulnerability Index (HVI) data for London



(d.) Healthcare facilities data for London

© Dr. Tanja Wolf / King's College London

© Created using data from OpenStreetMap. Note that the healthcare facilities shown on the map are not exhaustive.

The London boroughs with the highest and lowest HVI scores are indicated by dark grey and light grey shaded areas respectively.

Arup suggests a range of 'win-win' measures which can increase the resilience of elderly people to climate-related risks while contributing to wider sustainability and resilience benefits for cities and the urban population. These include:

- transform urban areas from 'grey' surfaces to green/blue areas (green space and water bodies) to increase the cities' resilience to floods and heat waves.
- design, build and retrofit buildings and infrastructure for future climate conditions, socio-economic trends and technological needs.
- enhance the existing heat wave and flood risk warning systems to ensure reliable communication channels which can reach all urban populations, including the most vulnerable people.
- ensure social services and public health programmes can be provided to the elderly during and after extreme weather events for access to energy, food, water, sanitation and medicines.

The combination of climate change, rapid urbanisation and ageing population is increasing the impact of extreme weather events for global cities and action is needed by decision makers and planning and design professionals to help alleviate the problem. With our methodology, the most exposed and vulnerable areas and communities in cities around the world can be identified and the right combination of strategic and operational 'win-win' measures can then be effectively targeted to these areas.

The final SHARPER research report and infographics are available at:
http://publications.arup.com/publications/s/sharper

Scan to download

This report is the result of a collaboration between Arup's Advanced Technology and Research team in London, University College London, King's College London, ClimateUK, HelpAge International and Satellite Applications Catapult.

Research at Arup

A collaborative pursuit of excellence

Research is the creation of knowledge inspired by the work we do and the challenges we face. It is fundamental to our continuous pursuit of technical excellence, integral to the way we do business and helps us to respond to the changing needs of our clients and the communities we serve.

Business driven

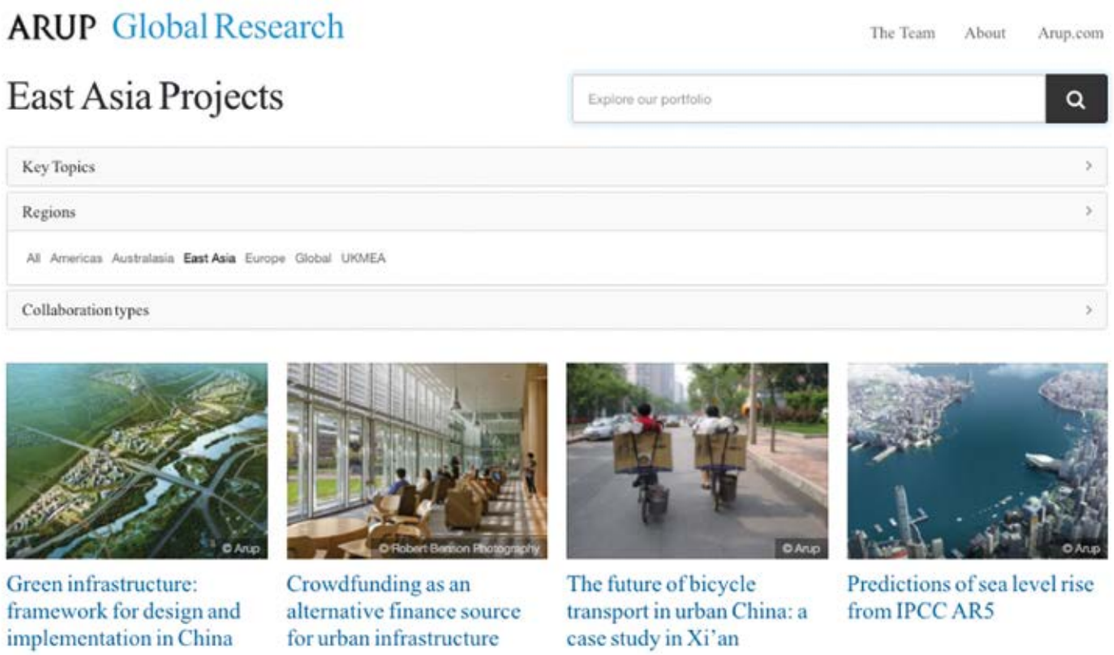
Research at Arup is driven by business needs and industry trends. Arup invests significant resources in about 500 R&D projects every year to strengthen our current business, accelerate the growth of new areas and explore and create future business opportunities.

Our staff can also initiate research projects to fill in the technical gaps identified in daily project work, either through research conducted within the firm or through partnership with academia, industrial partners and government/semi-government organisations. Every year, more than half of our research projects in the East Asia Region are collaborations with academia and industry partners allowing us to leverage on our partners' strength to co-create knowledge.

Global research website

To better showcase our diverse research works a collection of research stories are now available at the Arup Global Research website (**http://research.arup.com/**). The stories are grouped by skills, regions or collaboration types and summarise the key research findings, applications and impact of each research project.

We invite you to explore the broad range of topics we are working on.



Regional research agenda

In East Asia, we have also developed a 'Research Agenda' to consolidate the short-term (1-2 years) and long-term (5 years) business-driven development needs envisioned by our Skills and Business leaders in the region with reference to the current industry trends and priorities of our research partners. The latest research agenda has four themes which it aims to explore:

Circular Economy

With the increasing scarcity of resources the current 'take, make and dispose' economic model is unsustainable. How can we deploy the Circular Economy concept to re-design and keep products, components and systems at their highest utility and value at all times?

Emerging Technologies

How can we deploy the latest development in emerging technologies such as nanotechnology and biotechnology in the architecture, engineering and construction (AEC) industry?

Cities

Rapid urbanisation has brought many problems, especially in dense and compact cities commonly found in East Asia. How can we combat issues such as traffic congestion and pollution in cities while sustaining reasonable growth and designing liveable places for urban dwellers?

Digital

How can we ride on the wave of new digital tools and technologies to streamline the traditional engineering design process, improve work efficiency and bring in new values and services to the AEC industry?

We welcome research proposals from you to further elaborate on these individual topics. If you are interested in becoming our research partner or would like to learn more about Arup's research, please contact us at **ea.arupuniversity@arup.com**.

Bruce Chong

Combining study with career

Bruce, from Arup's Hong Kong Management Consulting team, has just completed his part-time PhD study after four and half years of research with The University of Hong Kong (HKU), becoming the first doctoral graduate supported by East Asia Arup University (AU). Here he gives us a glimpse into his research work and shares how he managed the study while working full time.

Why did you choose to pursue the PhD study through AU?

After my MPhil study, I switched my career from a mechanical engineer to a consultant in specific areas such as low-carbon development and sustainable infrastructure. Upon joining the Management Consulting team, I was fortunate enough to work on a number of projects addressing carbon accounting, urban resilience and resources planning – all these required me to develop analytical tools and frameworks.

These projects not only further fueled my interest in related topics but also helped me reach out to different people in academia including Professor Thomas Ng from HKU. I grabbed the opportunity when I learned about the AU part-time PhD programme and started my research with Thomas.

How does the joint PhD programme work?

AU covered my tuition fees and under the scheme I was given 40 days (320 hours) a year to meet my supervisor, attend conferences, complete course work and do the research. Of course, doing a PhD involves a huge time commitment – I spent around 15 hours a week in the early years, mainly at night and weekends, reading and writing, focusing on thesis writing in the last few months.

Tell us more about your research?

In Hong Kong, there is a lack of a robust approach to calculate indirect carbon emissions – researchers make use of either the process-based approach or overseas databases to make estimates. However, both approaches are constrained by data availability and accuracy, resource limitation and truncation errors. The input-output model provides a way out by capturing emissions of all economic activities across sectors.

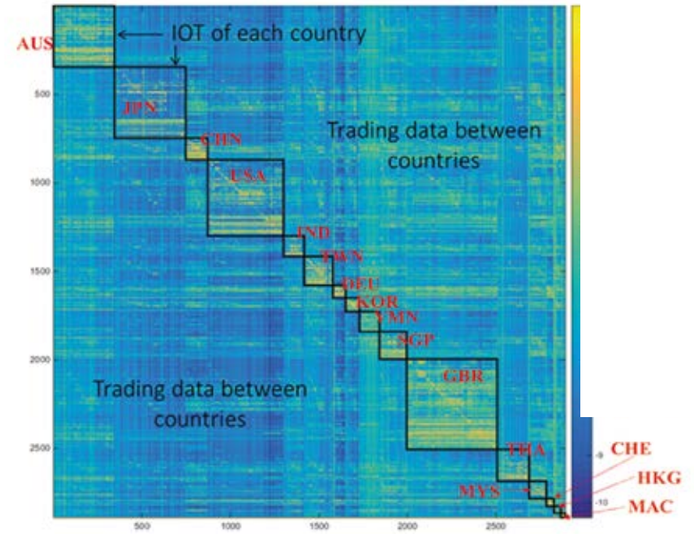
As Hong Kong has no official input-output table (IOT), its monetary IOT cannot be linked with international trade statistics and environmental parameters to identify the indirect emissions along the supply chain.

Hence, this research aims to determine how resources embedded in the upstream supply chain could be estimated. The research has formulated a methodical approach to derive an updated IOT for Hong Kong and compiled a multi-regional input-output (MRIO) table between Hong Kong and its key trading partners – a first attempt locally. The research has also derived emissions along the supply chain by using the updated IOT, its corresponding MRIO and available process data.

How did you make it achievable to perform a part-time doctorate?

Doing a PhD is like running a marathon – for most of the time, you only have the enthusiasm and moral support from your supervisors, friends and family to sustain you.

Luckily though, during my research, I found a team at The University of Sydney working on a similar topic with useful sets of data, data framework and computer models. I took two months off and worked as part of the team to co-develop the model, which significantly advanced my research.



Heat map for Hong Kong input-output table (37 x 37 sectors)

Country	No. of Sectors
Australia (AUS)	345
Japan (JPN)	402
China (CHN)	123
United States (USA)	429
India (IND)	116
Taiwan (TWN)	163
Germany (DEU)	72
South Korea (KOR)	78
Vietnam (VMN)	113
Singapore (SGP)	154
United Kingdom (GBR)	511
Thailand (THA)	180
Malaysia (MYS)	98
Switzerland (CHE)	43
Hong Kong (HKG)	38
Macau (MAC)	26
Rest of World	1
	2,892 (Total)

What do you find most beneficial during the process?

By nature, consulting work requires identification of core issues, formulation of a systematic and methodological approach for problem-solving and putting forward new ideas to create value. This demands a broad base of knowledge and skills in particular areas. A PhD study provides valuable and rigorous training in critical thinking, questioning, reasoning, approach formulation and data analytics – all of which are fundamental and will benefit our consulting projects.

What advice would you give to those who want to pursue part-time PhD study?

Act now, the earlier the better!

Bruce's dissertation is available at http://hub.hku.hk/handle/10722/236577

The Penguin Pool

When digital turns on creativity

The Penguin Pool is Arup's creative event which aims to encourage new connections and seed future collaboration across the design community.

The latest Penguin Pool, organised by the East Asia Arup University (AU), was held in November 2016 at the Hong Kong Maritime Museum. With digital technology being ubiquitous nowadays the theme 'When digital turns on creativity' was aptly chosen.

Four renowned speakers joined us from various digital-related fields — big data, robotics, live streaming and virtual reality — to explore how the digital world can help with innovation and creative expression in the real world.

Our guests were invited to capture the moment with our architectural projects (and penguins) using ArupReal, an Arup-developed augmented reality app that can generate real time 3D structures by scanning 2D codes. Several exhibits were also set up to showcase some of the innovative work that Arup has been doing using digital tools, including the HoloLens mixed reality headset and the Oculus Rift virtual reality headset which enable design solutions that users can 'touch', see and control. Furthermore, a microclimate simulation 3D model of the New World Centre project in Hong Kong allowed guests to visualise the airflow and lighting design using augmented reality. And a fire dynamics simulator of the Beijing airport demonstrated the fire and smoke evolution.

As part of AU's ongoing collaboration with universities and academic institutions, students from the Technology Leadership and Entrepreneurship programme of the Hong Kong University of Science and Technology were also invited to join the event. The students took the opportunity to present some entrepreneurial ideas and gained feedback from our guests to further improve their concepts.

The event demonstrated our dedication to pursuing innovation in our daily work, and guests were excited about the potential use of these digital tools in their business areas.

Timothy Suen
A design integrator

"I'm kind of a jack-of-all-trades who's eager to know and do lots of things," says Timothy Suen, Arup Fellow, Leader of East Asia's Rail Business and Skills Network in his hallmark chipper easy going manner.

Timothy (third from right) at the Dragages JV site, inspecting the workmanship of a circular column formwork he designed.

Timothy also designed the temporary sheetpile anchor wall for the approach tunnels

Nevertheless, he is a master of one – bringing together different disciplines to deliver successful rail studies and projects. To his great pride, he's now leading the Hong Kong Railway Group to work on the lion's share of MTR's five major expansion projects which will extend Hong Kong's rail network by 25%.

"I would rather call myself a design integrator," he says. In his opinion, an integrator is no less creative than a designer. This role is increasingly important in mega studies and projects like railways which involve a wide range of disciplines and interfaces, including civil, structures, MEP, rail systems, architecture, project management, planning, economics, procurement and financing.

Connecting the nodes

In retrospect, it seems that being a jack-of-all-trades is part of a journey to becoming a master of integration. "A journey to understanding the big picture, then establishing individual nodes and linking them together", says Timothy, drawing the analogy to building a rail network.

Prior to joining Arup in 1980, Timothy spent two years with a Dragages-led JV where he undertook MTR works and learned the methodology of construction intertwined with design. Then in the late 1980s, he had another 2-year stint with Wong & Ouyang Architects, working as a resident engineer on Pacific Place I & II directly reporting to the developer Swire Properties.

"Working with contractors, you have to be technically competent with contractual knowledge for delivering designs," he says, grateful for the experience that exposed him to the diverse interfaces and individual elements of the project process.

In 1989, he rejoined Arup in the Prime Agency Group. The group managed multi-disciplinary projects and took care of all those 'quirky' and 'fit-no-discipline' jobs such as way-finding and typhoon shutters. "At that time, the Hong Kong office was relatively small and I was able to work on most of the projects that I liked with many groups and across all disciplines."

Back then Timothy also moved around, working with different cultures on some of the most interesting projects in mainland China, including a brewery in Baoding and an electrical and electronics factory in Guangzhou. "I acquired a very broad skillset by working with knowledgeable and experienced Arupians who influenced me a lot in multidisciplinary thinking and working as well as heavy foundation design", he says.

Why finally settle in railways? "Just following the call of passion!" he replies in a cheerful voice, reflecting on the pivotal moment in his career. It was in the mid-1990s, and one day he was asked to attend two meetings to be held concurrently – one on an industrial project in the mainland, and the other on Hong Kong's West Rail technical study. He went to the latter and with Tom Larmour's unfortunate accident the leadership of the Railway Group became vacant and the rest is history!

Discover **Timothy's works**

MTR Island Line Wan Chai Station
Large diameter bored piles with manual bell-outs (probably the first of its kind in Hong Kong) and diaphragm wall design for the deep basement with in-house developed software to capture site monitoring data for back analysis.

Exchange Square I & II
Supervising construction of 400 large diameter bored piles in 6 months, a real race against the clock on this sleepless site! He also supervised the piling to structural topping out of Exchange Square III.

HACTL Cargo Terminal at Kai Tak
Design coordination in parallel with construction work, enabling the project to complete 6 months ahead of schedule and within budget.

Bangkok MRTA
Blue Line North Section
Bid design management for the 3 packages of works and winning the northern half of Bangkok's first subway network comprising 10km of twin running tunnels with nine stations.

East Rail Extension; East Tsim Sha Tsui Station & tunnels
Leading a multidisciplinary team for detailed design of the complex station, running tunnels and a pedestrian subway network in a dense urban area and acting as the 'Engineer' for the works contracts.

Cut-and-cover tunnels with 'stitching strip' gap. The temporary stitch joints allow movement of the tunnels during construction

Timothy in discussion with a project team

Future of rail: designing a total journey

Among all these successful projects, Timothy views his solution for Airport Express Kowloon Station and tunnels as the most significant so far. He originated the stitch joint design for a piled station connecting to an open cut floating cut-and-cover tunnel with some unconsolidated clay.

"The design is the first of its kind in Hong Kong and, probably for Arup, globally. The solution is now adopted as standard drawings by the MTR," he says with a sense of pride. "Of course, I believe my best technical solution is yet to come!" he laughs.

Timothy notes that changing passenger expectations and evolving technologies, such as driverless trains, signaling systems and real-time travel information covering multi-modes of public transport are making a profound impact on related design elements. Even the design tools we use have also been changing fundamentally. "The virtual reality and augmented reality tools nowadays are amazing," he exclaims. "All these digital tools create more time for us to think and try out more options with creativity."

"The future lies in how we leverage the most appropriate technology to achieve economic and commercial viability of projects to suit specific geographies and cultures whilst creating a total travelling experience," he reflects.

He sees a wealth of opportunity in the coming decade arising from the large-scale urbanisation in Asian countries, especially high-speed rails with China's 'Belt and Road' initiative, rubber tyre systems such as monorails and automated people movers in less dense cities or feeder services linking the metro network in mega cities, asset upgrading and whole life cycle cost management in mature markets.

In response, we must leverage our global skills such as traction power, electrification for railways and rolling stock, train control systems and asset management to improve the entire rail offerings in various skill hubs. "Most importantly, integrated project design management skills in planning, design and delivery of rail projects", he says.

Team chemistry is everything

As an Arup Fellow, Timothy now carries the mission to groom trans-disciplinary design managers like himself who can effectively integrate expertise for positive outcomes.

"To be an integrator, you have to widen your knowledge and make sure you understand the process and constraints before you challenge for a better solution," he advises.

He believes that an enquiring mind is essential in this increasingly specialised era when technologies are advancing at an unprecedented speed and scale. "You can always learn something, whether talking with colleagues or reading reports from other disciplines if you really want to understand the principle behind and see the full picture," he says.

Though an enthusiastic advocate of design integrators with a wide spectrum of knowledge, he also thinks it's totally fine to be a specialist with deep knowledge in a certain field. "It's often specialists that influence the final decision-making and that's why we need all kinds of people."

"Whether being an integrator or a specialist, the key is to play your own part in a team," Timothy opines. "To deliver a good design, we need a team with good chemistry apart from individual capabilities."

He suggests that everyone should first of all understand their team organisation, their role in it and others' expectations of them. "Then ask yourself: am I comfortable with that? If the answer is yes, show your commitment to delivery, learn from mistakes and feel proud of the outcome," he says.

"Don't work alone," he reminds us. "Always discuss your ideas and take up challenges from others. The wisdom of a group exceeds that of the wisest individual."

Eric Chan

A diligent pragmatist

"Technical drawing is the prerequisite for technical development. An engineer who cannot draw well will not be a successful design engineer."

As with many in Hong Kong, Eric grew up as a hardworking and adaptable lad. But two things that Arup's East Asia Infrastructure Head hadn't expected, apart from the people and projects he encountered in his past 35 years with the firm, were taking major roles in institutions and becoming a cycling enthusiast after being involved in a major cycling track project.

Technical drawing is the prerequisite

But before all that, Eric was very serious about 'drawing' roads and bridges. "Creating the whole road network right from penning it down on a piece of paper is what I take the most pride in," he says, "From conceiving the design, finding alternatives, through to its completion and open for people to use."

Eric first learned about technical drawing at a technical secondary school in the 1970s Hong Kong. Those engineering items he came across inspired him to become an engineer in the future.

He later obtained his civil engineering diploma at Baptist College (now Baptist University). After working with a Japanese contractor for a while, he got a chance to study at the Dundee University in Scotland for a full degree. He eventually joined Arup in 1981.

Go with the flow

Unlike its mammoth size today, the civil engineering practice at Arup's Hong Kong office was small. "There were about 20 people, mainly supporting the Geotechnics Group. Fixing the retaining walls near the Supreme Court buildings in Admiralty (now High Court) is one of the projects I remembered," he says. But Eric attaches the same importance to every task that flowed to him regardless of its significance.

"I had to learn along the way. It would be unimaginable for a junior engineer to be able to build, say the Stonecutters Bridge, overnight." Nevertheless, he managed to build his first vehicular bridge later in Hang Fa Tsuen, while his first footbridge was part of the 7-footbridge system associated with the 12.5ha Tuen Mun Town Park.

Eric Chan at the construction site of Hong Kong-Zhuhai-Macao Bridge (Hong Kong Link Road)

The eye opener

Several projects shaped Eric's versatile career. For instance, Kwun Tong Bypass was an eye opener as he witnessed the first time that the 'segmental construction technique' was used in Hong Kong in which the flyover was built in segments with post-tensioning.

"The team was like a 'league of nations' — The contractor brought in the French and Arup London sent Klaus Falbe-Hansen here to lead the project; we also had people from Pakistan, Sri Lanka, India and the Netherlands, plus two 'SUN' computers, pretty advanced at the time. After all, I learned a lot about segmental bridge designs during the process," he recalls. Such technique is still prevalent in bridge construction today.

How about a depressed flyover?

Eric later proved himself to be instrumental in securing the first lead consultancy in highways for Arup's Hong Kong office — building a flyover at Pokfulam Road/Sassoon Road Interchange to alleviate traffic congestion at that strategic link which runs along the hilly terrain of Hong Kong Island.

"The original brief would have had the flyover running right across the front of Queen Mary Hospital and it was unnecessarily so tall that it would hide the hospital behind. Alternatively, I suggested a depressed link along the slope, a slightly challenging but logical proposal, and in the end everyone was very happy," he explains. The graceful outcome was well received and raised Arup's profile in Hong Kong's infrastructure market.

Exhaust all options

As with his passion in spontaneous drawing, Eric became eager to propose as many options as possible in projects. He even developed a matrix to compare development options during a feasibility study about relocating the Hong Kong Police's Explosive Ordnance. This feasibility matrix remains to be useful within the office as well as supporting the conclusion of option assessment for various large infrastructural projects.

Eric is also proud of his Deep Bay Link, a 5.4km long dual 3-lane carriageway towards the Hong Kong boundary. "I significantly changed the highway layout in the design brief, proposing more exits while reducing the amount of land needed for resumption, with

Kwun Tong Bypass
First project in Hong Kong that involved segmental deck construction.

The depressed flyover
At the Pokfulam Road/ Sassoon Road interchange.

© Camera Vision Studio

Deep Bay Link
A 5.4km dual three-lane expressway comprising viaduct and bridge structures

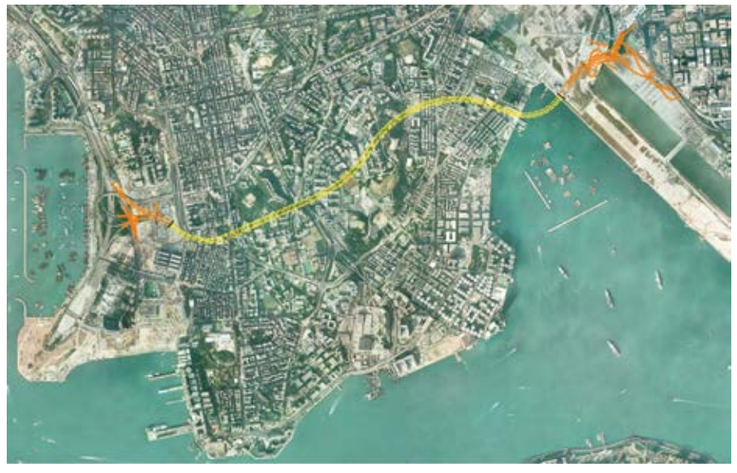
many road options for linking the co-located control points. The success led us to another investigation-design-and-construction consultancy of the adjacent Shenzhen Western Corridor (Now Shenzhen Bay Bridge)," he says.

Identity crisis for civil engineers

Given all these successful stories, it doesn't mean Eric has no qualms about where the trade is heading. He feels that civil engineers nowadays have less 'authority' over the project designs due to changes in society expectations and diversification in the engineering discipline itself.

"Highway engineers used to decide everything about roads network, but today you have to consult many disciplines. Now you have traffic and transportation engineers present you the figures to determine the routing," he says, "Ventilation and evacuation in vehicular tunnels must be advised by specialists and authorities."

"Environmentalists and the affected communities will also make their voice heard, let alone public scrutiny as to whether we need a bridge or a tunnel.



The Central Kowloon Route links its East and West in a speedy journey

Lots of efforts have been channelled into co-ordination and consultation," he laments, "in many cases, the acceptable option could be the most expensive option."

Escalating demands

Asked whether the change was due to the raising awareness over city design and quality of life among the public, Eric insists one cannot rule out technical consideration in reality and the inevitable costs involved if one shoots for a higher goal.

"Planter boxes with soil on a footbridge for the sake of greening can easily double the live load and drive up the cost." he says. "Flyovers are sometimes regarded as eyesore today, but tunnelling is way more expensive in terms of construction, operation and maintenance. But of course, it's very difficult to tell which option will be better overall."

One of his ongoing projects – the Central Kowloon Route – is a 4.7km long dual 3-lane trunk road where most of it will be a road tunnel sunk beneath the urban areas, but the journey time from Kowloon Bay to Yau Ma Tei which is a 30-minute journey today will be drastically reduced to 5 minutes.

"As a pragmatic civil engineer, I believe a good design should always be something that provides the intended function with the minimum cost," he says. "Safety should be the primary concern in road designs." he emphasises.

When asked about smart mobility, "Roads in particular bridges are designed with an average life span of 120 years. Drivers could be replaced by computers, but vehicles will still run on roads in the near future." he says.

Unexpected rewards

Beyond work, Eric also wore several heads externally. That includes chairing the Hong Kong Branch of Institution of Highways and Transportation (now CIHT) and the Civil Division of the Hong Kong Institution of Engineers (HKIE) as well as the Logistics and Transportation Division.

Eric in an HKIE visit to Sichuan, China, observing its post-quake recovery.

Eric at 2015 Hong Kong Cyclothon

Eric as the Civil Division Chair at HKIE

"Those posts came to me unexpectedly as I was asked to help out." he says. "It's indeed some extra work but it's worthwhile to serve the engineering community and the society at large in an external capacity."

Becoming a cycling enthusiast is another exception over the course of his engineering life — he literally cycled around Taiwan and also challenged Qinghai Lake.

That hobby came from his involvement in an investigation study about planning a 22km-long cycling track started in 2009.

"To speak the same language with the cyclists and, to design a user-oriented cycling track, I had to be a cyclist first to get into their minds. Just that I didn't expect it would become one of my interests in the end," he laughs.

So, finally, advice to young engineers? "Just with the old phrase: put yourself in someone's shoes," he says. "If you think your client has been harsh to you, be in their situation then you will understand their predicament too."