Foresight ▸ Innovation ▸ Research ▸ Sharing ▸ Training

Issue 4 2017

FIRST

The rail challenge:
MTR Kwun Tong Line Extension

ARUP

Welcome

We are very excited to be sharing with you in this issue that we have been scored 'excellent' in the Fuji Xerox Hong Kong first-ever 'Enterprise Innovative Efficiency Capability Index' (EIECI), coming in the top 2% of entries. This is a clear recognition of our commitment to creating value through innovation and a result of our continued support of good ideas and collaborative research.

In this issue, you will read about how our out-of-the-box approach is helping cities explore new dimensions for an improved urban experience:

- Projects like the MTR Kwun Tong Line Extension in Hong Kong and the Elizabeth Quay Pedestrian and Cyclist Bridge in Perth demonstrate good examples of our capability in revitalising city centres through improved connectivity;
- From realising the unique shape of the China Resources headquarters to designing an efficient vertical transportation strategy for Changsha International Finance Square, we continue to help our clients tackle some of the greatest challenges facing vertical urbanism;
- Our legacy-driven approach is shaping the new town of Zhangjiakou for the 2022 Winter Olympics.

All these cutting-edge solutions are firmly underpinned by our continuous research to understand the future and to find a better way for design, especially the exploration of what digital technology can offer. There is a range of foresight reports and research projects in this issue, from emerging technologies affecting the engineering and construction industry to an assessment tool that helps cities better understand their climate challenges and improve the way they coordinate their policies.

Arup is all about people – they are at the heart of the firm and its pursuit of quality and creativity. Among the people featured in this issue are Wilfred Lau, who initiated the Smart Green Resilient concept to develop Asian cities, and Goman Ho, the man behind many of Asia's most impressive skylines.

We hope you enjoy the 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****.*

The rail challenge:
MTR Kwun Tong Line Extension

Client:
MTR Corporation

Arup's scope of services:
Full engineering and management including architecture, MEP engineering, human factors analysis, risk management, value management, construction planning and building information modelling

The MTR Kwun Tong Line Extension (KTE) is a 2.6km line from the existing Yau Ma Tei Station to the new Ho Man Tin and Whampoa stations which opened in October 2016. The route runs below various densely populated areas of Hong Kong and presented numerous challenges during the design. Arup was the consultant in the major design packages of the KTE Line, including the preliminary design (route alignment), tunnel construction and the scheme and detailed design of Ho Man Tin Station.

Alignment design

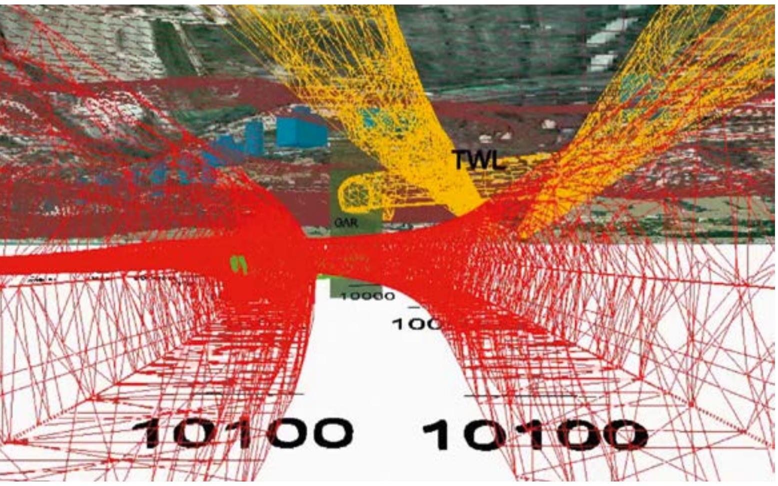
The alignment of KTE was limited by factors comprising: private land, hospitals, service reservoirs, major roads, existing railway lines, existing underground conditions and the impact of construction on the neighbourhood. The Arup team explored up to 13 different alignment options, involving detailed analysis and cross-comparison, resulting in the most suitable, cost-effective and risk managed option.

Location of private lands
The KTE tunnel inevitably passes underneath existing buildings along the route. To avoid the risk of claims for loss of development value, Arup optimised the route, while still providing an alignment acceptable to the MTR. Despite this, challenges were still encountered given the other sensitive structures and properties, such as the Queen Elizabeth Hospital and some Water Services Department service reservoirs close to the site.

Existing underground conditions
Given the complexity of the underground environment, Arup coordinated various geotechnical investigations to better define the risks and to reduce geological uncertainties. The Arup team located obstructions, such as foundations, old air raid tunnels and utilities, and produced a large project database with building foundation and borehole data for the whole project area. Based on the information collected, Arup carried out detailed 3D ground and obstruction modelling to ensure that the KTE alignment had sufficient clearance from identified obstructions.

Arup's thorough geotechnical investigation also accurately identified locations of poor ground which the KTE alignment avoided as much as possible. However, the KTE tunnel could not avoid soft soil and faults along Wuhu Street, below the King's Park Sports Ground and near the existing East Rail Line. Advanced knowledge about the ground conditions in these areas enabled adequate contingency measures to be made to stabilise the ground for excavation, thereby minimising construction cost and risks.

The final KTE alignment and its cross-interchange with the Shatin-Central Link Location of private lands



Flythrough videos along the KTE route were produced to help identify underground obstructions

Impact on existing and future structures

Design of the KTE alignment took into consideration the Gascoigne Road widening plan to ensure that the tunnel would not impose any negative impact on the future road foundations. Arup also coordinated with the consultant for the Gascoigne Road upgrade, agreeing on the road piling layout and additional loading conditions.

During the later stages of the design, Arup was informed that a new school was planned at the former Canterbury Court and Worcester Heights government residential blocks near Wylie Path and very close to the proposed alignment. This new school had more robust and deeper piles than Arup had anticipated and led the team to re-evaluate the alignment design, which was adjusted to ensure enough clearance to the deeper foundations.

Some existing structures were affected by the KTE project such as: the site of the Wylie Road Ancillary Building, used for tunnel access during construction, overlapped with the existing tennis courts of Club de Recreio and; the YMCA King's Park Centenary Centre was found to be susceptible to potential blasting and excavation vibrations. The Arup team demonstrated to the concerned property owners what level of vibration would be encountered by using vibrograph equipment and asking them to produce their own vibrations by stamping on the ground or knocking the table. This demonstration successfully allayed their concerns and made the negotiation and acceptance of the project vibration impact much easier.

Tunnel design and construction

Vibration control

Construction of the KTE tunnels involved blasting at locations close to densely populated residential areas posing major safety concerns. To evaluate the impact of blasting on the sensitive structures above ground, an in-house Geographic Information System (GIS) based blasting assessment tool was specifically developed. The automated calculations helped to determine the amount of explosives that could be used without compromising the sensitive structures at the surface. It also saved time in reanalysing allowable explosive charge weights when new or updated information became available.

Blasting for tunnelling under Wuhu Street, which had old buildings more prone to vibration impact, was particularly challenging. To ensure the buildings' structural safety, the Arup team specified, for the first time, the use of electronic detonators. These detonators allowed precise control of blast timing, which can reduce equivalent blast vibrations by up to 30%.

Tunnel excavation

Hong Kong's geology is mainly composed of hard rock and drill and blast excavation is the most suitable and cost-effective approach. However, some sections of the alignment had poor ground conditions with soft soil and faults which had to be mechanically excavated. A combination of grouting and robust steel reinforcement was employed to provide additional structural support for the weaker ground anticipated, and eventually encountered, during construction.

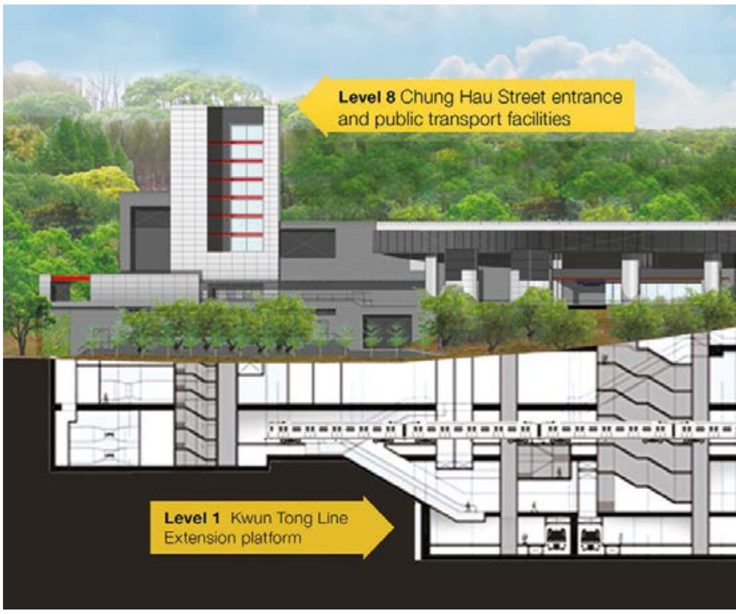
Combating the groundwater

Underground construction could potentially alter ground water level and pressure, thus posing threats to the structural safety of nearby buildings. During the design stage, Arup built various hydrogeological models to identify the allowable groundwater inflows and simulate the grouting potentially needed to seal the rock surrounding the tunnels. The team also designed an underground drainage system so that surplus water in the sump would be actively pumped out.

Buildings with wooden piles and old historic buildings along and near Wuhu Street particularly required careful groundwater control. Arup designed a fully sealed undrained tunnel along this section to ensure that long-term impact from minor seepage would not damage these sensitive structures.

Enlarging an existing cable tunnel

One special challenge for the KTE tunnelling work was the enlargement of a 20m long cable tunnel of the existing Kwun Tong Line to form KTE's new running



A small size jack hammer was used to enlarge the cable tunnel of the Kwun Tong Line

tunnel. As the cable tunnel had a small access hatchway (2.5m x 2m), excavation by large size mobile machinery was difficult; a small size jack hammer was then used to increase the headroom by 4m. Although the excavation work took 200 days, the thoroughly planned work sequence ensured that the Kwun Tong Line service was not affected.

Ho Man Tin Station

Ho Man Tin Station, located beneath a filled platform bounded by Fat Kwong, Chung Hau and Yan Fung streets, will be an interchange station for the future Shatin-Central Link (SCL). Faced with challenges posed by the cross-alignment of KTE and SCL and the abrupt 68m level difference between the ground and the lowest platforms, Arup's architects adopted a cascading approach for the station design.

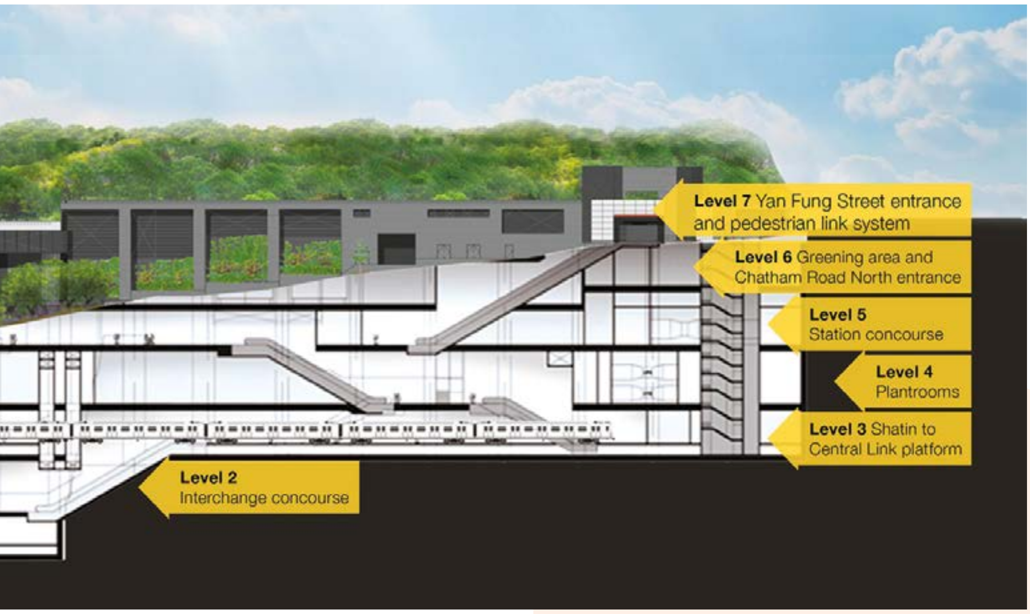
The cascading approach

Ho Man Tin Station has eight storeys, housing the KTE platforms on L1, an interchange concourse on L2, the SCL platforms on L3, plant rooms on L4, the station concourse on L5 and the various entrances on L6, L7 and L8 connecting to the pedestrian link systems and public transport facilities. Arup adopted this cascading approach to minimise the station's footprint, keep passenger flow decision points to a minimum and provide efficient vertical circulation. Location of the escalators was also strategically determined based on passenger flow simulations. In particular, the interchange concourse on L2 offered additional space for installation of escalators to distribute passengers from both KTE and SCL.

The station depth and cross-alignment of KTE and SCL presented fire engineering challenges. Arup was engaged in negotiations with the government department at an early stage to ensure that the design met government fire safety requirements. Direct access for the fireman's lifts from the street level to the lowest platforms is impossible for this station, so intermediate transfers between fireman's lifts were proposed. The platforms and concourses of the station are all equipped with essential sprinkler and smoke control extraction systems. L4, with only plant rooms and no passenger access, also has smoke control extraction systems installed at corridors to further enhance safety. The stairwells for public stairs are installed with door openings for dispersal of smoke in case of fire. All these design features were responses to fire safety requirements arising from the depth of the station.

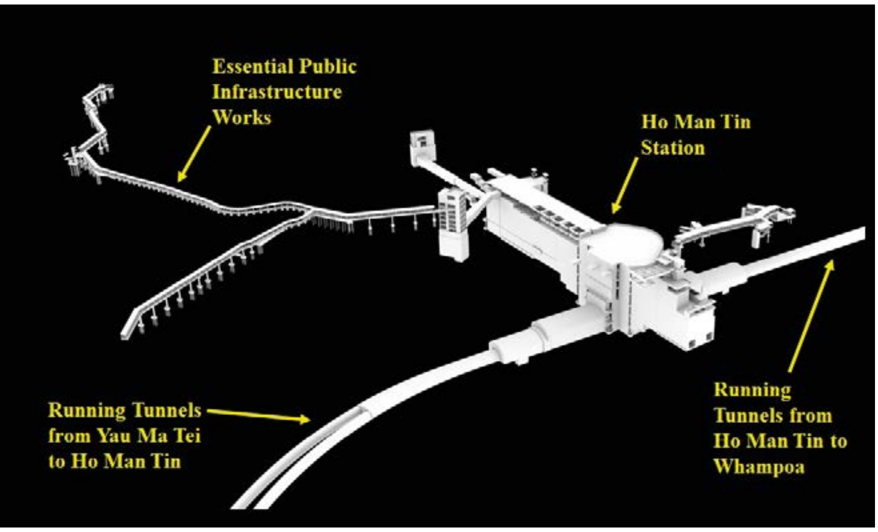
Entrance design

To determine the most strategic locations of the station entrances, Arup conducted patronage calculation studies. The studies showed that about 80% of the passengers would be coming from the Hung Hom area and the entrance facing Chatham Road North was thus designed as the main entrance. An external corridor links this entrance to Wuhu Street. The other two entrances respectively lead to Oi Man Estate and the essential public infrastructure works (EPIW) connected to Ho Man Tin Estate. Arup was responsible for designing the 1.2km EPIW, comprising covered walkways and subways.



The Chung Hau Street entrance at L8

Ho Man Tin station adopts a cascading approach



The project used BIM to facilitate compatibility of various design solutions

All coordinated in BIM

Arup used BIM to offer a fully integrated and coordinated model for clash detection and visualisation. This was MTR's pilot project for BIM and it is now being deployed in other MTR projects to enhance construction efficiency.

Open-cut method of construction

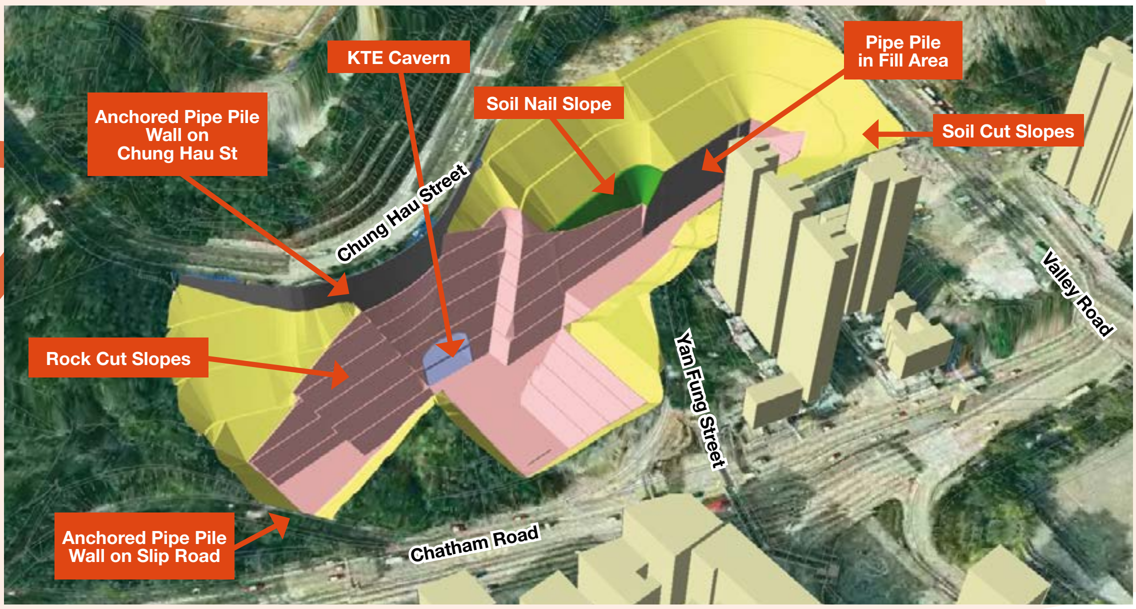
The entrance at Chung Hau Street and the KTE platforms have a massive 68m height difference. During the design stage, Arup considered both cavern and open cut schemes and their 'potential risk costs' were evaluated. Such risk analyses with quantified costs were novel for MTR projects at the time. The analyses indicated that the open cut method was a more desirable option offering a better interchange layout and resulted in the deepest open cut station so far built in Hong Kong.

One of the core challenges of the open cut construction was dealing with zones of weak weathered rock and soil which could subsequently lead to overall failure of the hillside. Televiewer logging of the boreholes was carried out to identify any major planes of weakness across the site. During excavation, the overall stability of the hillside was closely monitored with devices to ensure that the temporary support for the excavation was structurally sound and stable.

Ho Man Tin Station site excavation took place right next to residential buildings and roads. A metal mesh was installed during blasting to catch fly rock

Blasting downward

Another major challenge concerned the excavation of the rock by blasting. The site is in a densely populated area with a major highway 10m from the site boundary which could not be closed. The Arup team had numerous rounds of discussions with the government to agree on a possible blasting approach to ensure public safety. For blasting at high elevation levels within the site and not deep below the



Geotechnical features around the deep excavation of Ho Man Tin Station

■ Before and after a blast

original ground surface, a double cage blasting protection system was used for the first time in Hong Kong. As the blasting went deeper, a full roof-over cover with steel netting was installed over the blast areas to contain any potential fly rock. The whole operation was carried out safely with no incidents from over 500 blasts.

Groundwater challenge

As in the case of the KTE tunnel, groundwater control was essential for station construction. As the station interrupted the natural water flow from the nearby hillside Arup proposed a drainage bypass scheme as a solution. This diverted the water flow around the station, thereby limiting upward recharge and blocking of the natural groundwater flow. This solution effectively reduced the design water pressure on the station and thus the amount of reinforcement used in the permanent concrete structure.

Ready for future development

One of the final challenges concerned MTR Corporation's residential development planned on top of the station. Arup installed piles for the housing complex during the open cut construction as enabling works to avoid abortive construction in the future. To ensure that any further piling works in other portions of the site are feasible in the future, Arup suggested using glass fibre, rather than the conventional steel, for slope stabilisation. The Contractor took up this suggestion and the slope finally became one of the world's largest open cut glass fibre reinforced soil cut slopes.

The complex KTE project was made possible through close collaboration between Arup, MTR Corporation, the contractor, various government departments and other stakeholders. The success of this major rail project highlights our professional and creative approach to engineering solutions.

■ One of the world's largest glass fibre reinforced soil slopes

The next level in vertical transportation: Changsha International Finance Square

Client:
Wharf China Development Ltd

Arup's scope of services:
Full building services engineering

Changsha International Financial Square (IFS) in southern China illustrates how an efficient vertical transportation (VT) system plays an instrumental role in making large, mixed-use commercial developments successful.

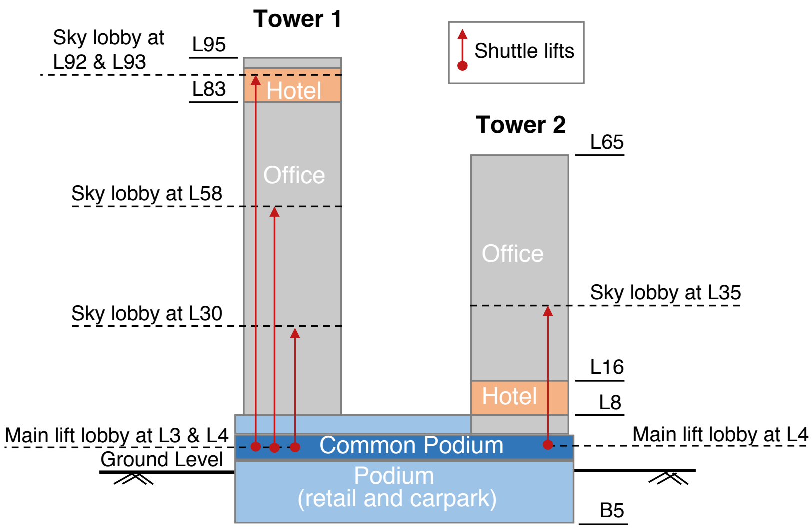
Serving the vertical community

When complete, Changsha IFS will host the tallest building in Hunan province. With a GFA of 1Mm² it has a podium with a 5-storey basement along with two mezzanine levels and seven storeys above ground. Sitting atop the podium are two towers – the 95-storey Tower 1 (T1) and 65-storey Tower 2 (T2) with heights of 452m and 315m, respectively.

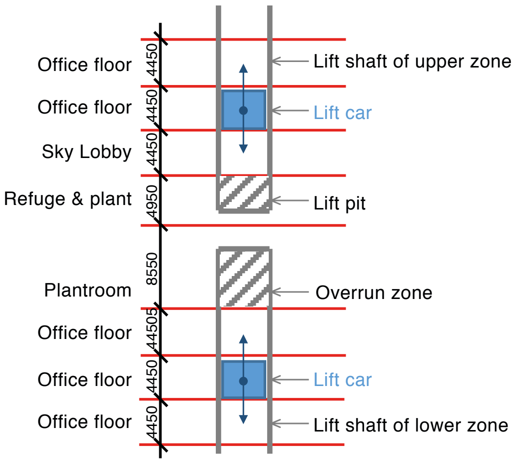
Defining the strategy

The VT design presented a number of challenges due to the height of the towers, the large population and the need to keep journey and waiting times short. Because of the multiple functions of the two towers and the proportion of office occupants compared to the hotel occupants, two separate lift systems were required in each of the towers. This article focuses on the VT system in T1.

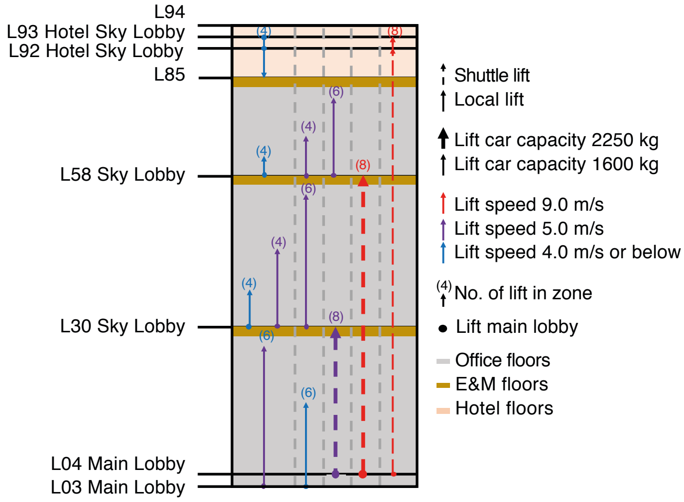
Arup's solution for Changsha IFS is to incorporate sky lobbies. These are intermediate interchange floors higher up the building and the only stopping point for shuttle lifts ascending from the main entrance lobby. These high capacity, high-speed shuttle lifts allow people to travel quickly up the building before transferring to a local lift service, thus reducing the total passenger transit time and the number of stops. This arrangement enables lifts to be stacked into zones, allowing multiple lifts to be operated within a single lift shaft, thus reducing the building core size and freeing up more lettable floor area for offices.



■ Offices occupy the majority of both towers, with a hotel occupying the top of T1 and the bottom of T2



Location of the lift shafts, sky lobby and refuge floor under the stacking arrangement



Conceptual diagram showing the lift stacking arrangement in T1

The sky lobbies need to be placed above the refuge and plantroom floors, so that there is sufficient depth for the lift pit of the local lifts above and also to accommodate the overrun of the local lifts below. This limits the locations of the sky lobbies and the flexibility of the stacking arrangement. The analysis revealed that two sky lobbies would be needed to serve T1's offices. An independent shuttle lift zone with two sky lobbies at levels 92 and 93 will serve the hotel.

Optimising the journey

For T1, the VT strategy was based on the client's requirement for an up-peak handling capacity of 11% – the percentage of the building's population that needed to be transported by lift during the most demanding 5-minute period in the morning. This equated to 1,419 people.

In traditional lifts traffic planning, only simple calculations based on the conventional equations from The Chartered Institution of Building Services Engineers (CIBSE) Guide D are carried out to determine the interval and handling capacity of a group of lifts. However, this may not be able to reflect the comprehensive population flow inside the building and the real time performance of the lift system. In this project, Arup adopted a new design methodology to compare different lift configurations that satisfied the handling capacity (11%) for a different number of lifts, car sizes and travelling speeds. In addition, simulations were run to optimise the lift provision and verify that the lift sizes and speeds would be adequate for the maximum number of people travelling up the building in the morning. The lift interval (the average time between successive car arrivals at the main lobby) of 35 seconds and 80% lift capacity were applied to the final VT design.

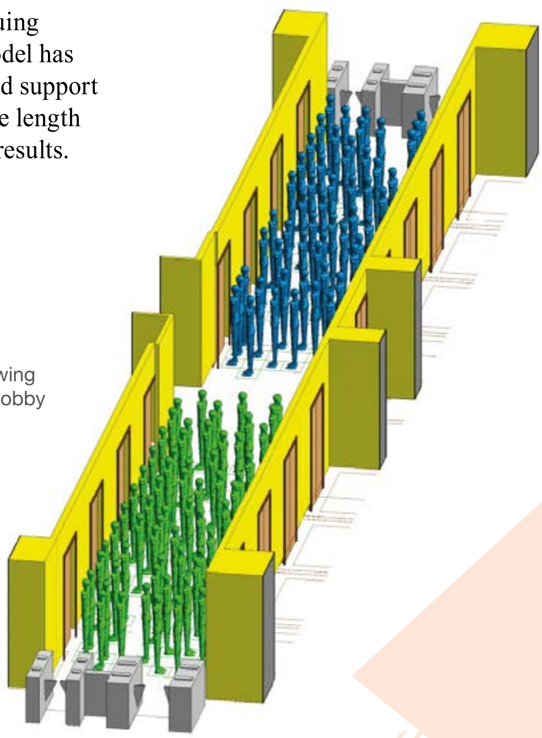
This new methodology also made investigating different configurations simpler. When the number of office floors changed from 60 to 68 during design development the number of lifts served within each zone and lift speeds were quickly altered to absorb these extra passenger loads without requiring additional lifts.

To ensure comfort for the queuing passengers, a 3D computer model has verified that the lift lobby could support 70 people, the maximum queue length determined by the simulation results.

The final lift system design concluded that 64 separate passenger lifts would be required for T1, stacked vertically in 'zones' to suit the office and hotel arrangements and the shuttle and local lift requirements.

Improving performance

Arup's VT strategy offers multiple benefits. It ensures the lift system can meet the 5-star service level (i.e. the average waiting time is smaller than or equal to 20s and the average transit time is smaller than or equal to 80s) according to CIBSE Guide D. The building core efficiency has also been maximised without compromising the performance of the lift system.

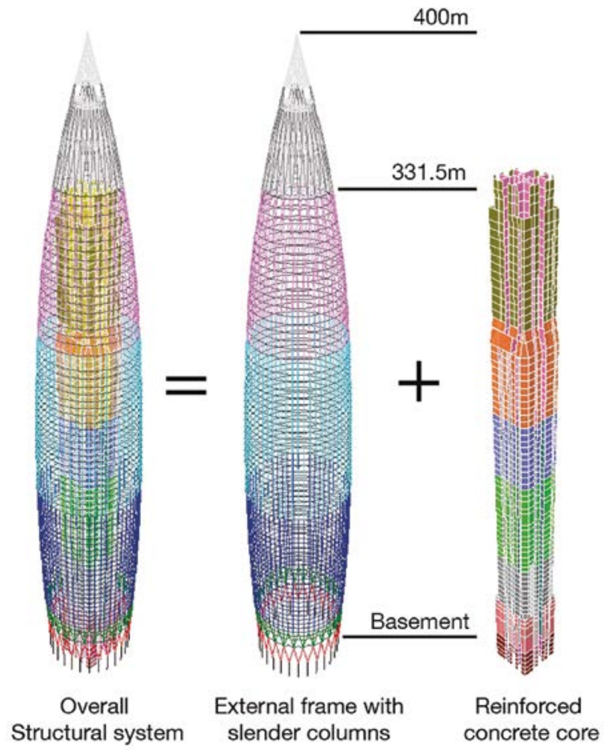


3D computer model showing 70 people waiting in the lobby

Departing from tradition: China Resources headquarters, Shenzhen

Client:
China Resources Shenzhen Bay Development Co. Ltd

Arup's scope of services:
Structural engineering, geotechnics, façade design and fire safety strategy



Structural system of the CRC HQ

With all the construction works completed, China Resources headquarters (CRC HQ) is making a fresh addition to Shenzhen's ever growing skyline.

Catalyst for a 'headquarters economy'

The local government is developing the Shenzhen Bay area into a 'super magnet' for headquarters of large Chinese and international companies, and the 400m tall 'bamboo shoot' like CRC HQ is one of the flagship projects.

Unique structural system

The main structure is 331.5m tall and the structural system is composed of a perimeter steel tube and a reinforced concrete core. The floor beam layout is mainly radial, which helps to resist the in-plane tension in slab that is induced due to the unique structural form. The spire crown at the building top is 68m high made of steel grid and trusses.

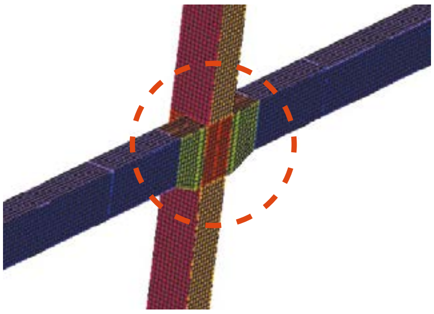
To fully reflect the architect's intent of the building shape, Arup designed a close-column frame with 56 external slender columns stemming from the diagrids at the bottom and converging into a crystal cap at the top. Compared with traditional mega-column and sparse column frames, this close-column system is structurally more efficient in vertical load transfer and requires a shorter construction period. It is the first time this structural system is used in a mega-tall building in a seismic area in mainland China.

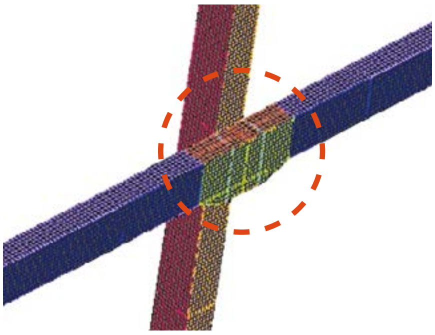
For tall buildings under wind loads, partial wall piers need to resist tension and shear simultaneously. Excessive tension force could induce cracks in concrete walls and that would reduce wall shear capacity and cause load redistribution. Since most of the lateral loading is resisted by the core in CRC HQ, the effect of tension force was carefully studied. As there were no test-based guidelines and specifications for such design in mainland China, Arup developed a whole-process design approach using finite element analysis to better understand the wall behaviour under wind and seismic loads.

In particular, Arup carried out a research study to examine how the tension forces reduce the walls' shear capacity, stiffness and ductility so to define the most suitable solution.

Eccentric beam-column connection to create column-free space

Several other pioneering solutions were also adopted. These include the bold and innovative use of the eccentric beam-column connections for the whole perimeter frame, which creates a 100% column-free office space while maintaining the architectural elevation design intent.





Normal beam-column connection (above) and eccentric beam-column connection (below)

A 100% column-free interior leaving the vertical column as external features

From technical point of view, the eccentricity leads to uneven stress distribution at the connection, resulting in connection failure. To ensure that the strengtheners in the connections can effectively transfer the force, all the connections are carefully analysed by finite element software.

Conversely, the eccentricity reduces the restraint from the beams to the columns and thus affects the stiffness of the columns as well as the whole building. Specimens were tested to verify the stiffness, capacity, ductility and failure mode of the connections.

This is the first time a mega-tall building in mainland China has used totally eccentric beam-column connections.

Tapered core to increase floor area

The floor plan reduces as the building goes up. To increase net floor areas, apart from reducing the core wall thickness, a tapered core was adopted in the building's high zone. To realise this, steel plates are embedded in core lintel beams to increase their stiffness and capacity to resist the horizontal forces induced in the tapered core. This approach has now been widely used for other super-tall buildings in China.

Outrigger damper to reduce wind vibration

The wind tunnel test for the tower showed that the wind induced vibration at the highest occupied floor almost reached the China code limits for office buildings. To provide a high level of occupant comfort, the client and the design teams experienced the same vibration in a motion simulator at the Hong Kong University of Science and Technology. The client then determined to reduce the level of vibration equivalent to the limit for Chinese residential buildings.

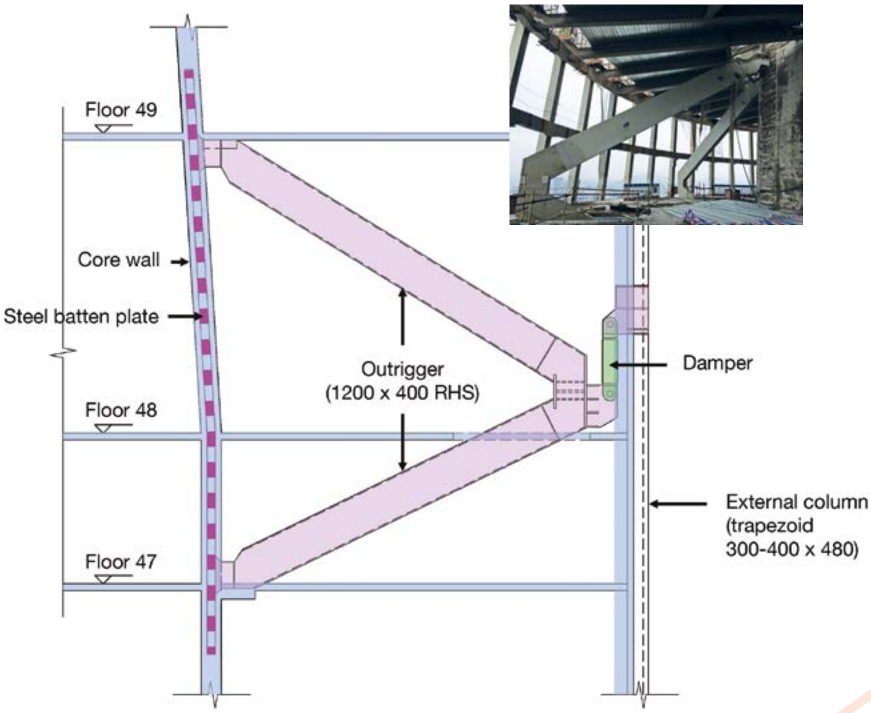
At the time that the decision was made, the building construction work had already started leaving limited choice of feasible measures. An outrigger system with eight viscous dampers was considered the best option.

The outrigger system takes the form of stiff 'arms' which connect the reinforced concrete core walls to the perimeter steel columns. Customised dampers were positioned between the outrigger and perimeter column. The damping effect and system layout are maximised considering the load capacity of the slender perimeter columns and the response to wind from 360 degrees. This is the first time high-powered viscous dampers have been used to control wind vibration in mainland China.

Optimising the process and results

During the design process, Arup used Rhino and Grasshopper 3D parametric modelling to visualise the details and optimise the design. The 3D modelling has effectively integrated the complex geometry with the façade, which has been well received by the client. Using the advanced structural optimisation technology, Arup was able to understand the cost sensitivity of the structural system components and optimise its dynamic properties and stiffness. The steel tonnage of this tower is ~17% lower than a typical 400m tall building in China.

Arup's engineering solutions brought considerable value to the success of this project.



The outrigger system installation at the plant and refuge floor at L47 to L49

A legacy-driven approach:

Planning for the 2022 Winter Olympics town and beyond

Client:
Zhangjiakou Chongli District Urban and Rural Planning Bureau

Arup's scope of services:
Urban design and planning

A 50-minute high-speed train ride from downtown Beijing, Zhangjiakou in China's Hebei province is one of three sites holding the 2022 Winter Olympics. Taizicheng of Zhangjiakou will stage most of the snow events and Arup is one of the four teams providing planning schemes and urban design for this 3km^2 Olympic town. This article looks at the scheme proposed by Arup.

Taizicheng is located in a pristine natural environment blessed with clean air, lush green mountains and vast prairie fields providing solid opportunities for regional growth. Preserving these natural assets and sustaining the Olympic legacy present formidable challenges to designers.

Arup's 'legacy concept'

Building on Arup's experience on previous world sport events, Arup's Shanghai Planning team and London Integrated Planning team worked together to propose a legacy-driven strategy which optimises the investment while ensuring a long-term, sustainable and lively post-Game transformation to drive urban growth in the Zhangjiakou area.

The design team worked to create legacy through flexibly transitioning much of the post-Games excess capacity to long-term growth drivers, covering both spatial considerations and industrial, cultural and sustainability strategies.

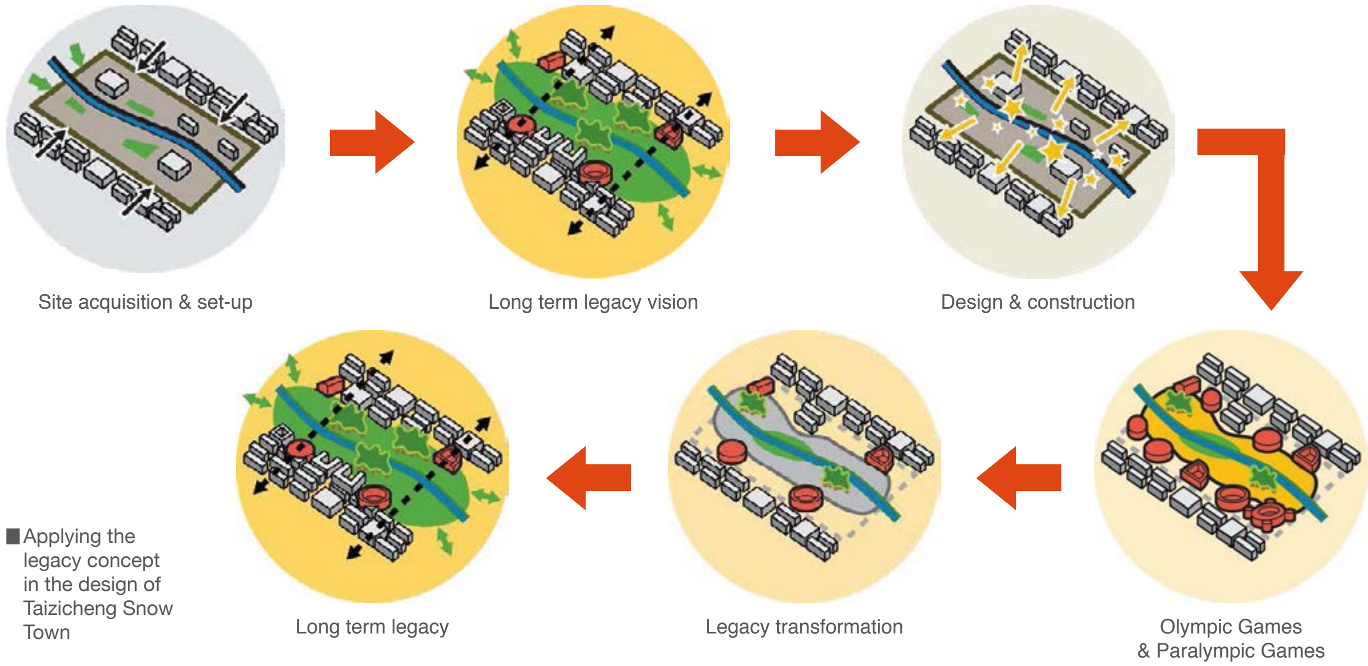
In our long-term development strategy, there is an action plan aimed at exploiting the catalysing forces of the Games to develop multiple industries — tourism and sport, health and wellness, and culture and media. This diversified development strategy can balance the local seasonal differences, and also link up the local economy to the large population in Beijing-Tianjin-Hebei region. The new economic structure will be a springboard to foster a strong local civic culture and sense of belonging. Through these measures the town will become a home for residents and professionals and an all year round destination for tourists.

Regional TOD hub

Significant effort was placed on developing the inherent potential of the high-speed rail station as a transit-oriented development (TOD) hub to catalyse future growth in the region.

The high-speed rail station will bring in a critical mass of visitors to Taizicheng. More than simply an interchange, the station is transformed into a destination and tool to experience the town as a whole, creating added value and decreasing peak pressure on the station in the process.

The station also makes Taizicheng a key hub for the development of Zhangjiakou's new industries. For instance, the design team reviewed the facilities at the neighbourhood ski resorts to identify what facilities are lacking and strategically introduce those missing facilities at the Taizicheng hub. This produces a resource sharing synergy for the whole area and increases the competitiveness of the region.



Applying the legacy concept in the design of Taizicheng Snow Town

Urban design measures combined with the station's location at the centre of town allows Taizicheng to consolidate the regional transit network, increase efficiency and effectively interconnect the sports venues, town and station while enhancing visitor experience.

Merging town and nature

Arup merged the town structure with nature to ensure a continuous visual connection to surrounding mountains via major public spaces and 5-minute-or-less access to the adjacent hills and prairies from any point within the town.

We also chose to break from the standard large plot sizes of most Chinese new towns, resulting in a town massing sensitive to its context with diverse, idiosyncratic buildings and an intricately woven, human-scale and pedestrian-friendly street network. The building massing is designed such that nearly all buildings within the site retain unfettered visual access to the surrounding hillscape.

The existing valley floor in Taizicheng is retained as a pair of large public open spaces. They are lined by courtyard developments and provide a place to walk and a 'sponge' for potential flood. The gullies converging at the heart of the town form key routes up to the residential neighbourhoods, integrating water systems and ecological corridors.

Olympic Square: a public space that combines TOD principles with cultural and commercial activities and persistent connection to nature

A detailed lighting strategy was created to preserve the local ecosystem and maintain a balanced human metabolism throughout the circadian cycle, as well as ensure residents and visitors are still able to discern the Milky Way galaxy from the town post-development.

These strategies can be seen as working toward a new model for the development of Chinese town planning around unspoiled natural sites. This model combines a robust step-based economic development plan with sensible, context-based massing and scale limitations as well as a careful application of state-of-the-art lighting measures. These are all built upon the foundational premise that un-manipulated nature should be accessible to all residents.

We believe the fruits borne continues in the Arup's tradition of commitment to context-sensitive design through innovative, pioneering and integrated solutions which push the envelope of business-as-usual.

© Jacaranda Photography

Simple elegance from digital design: Elizabeth Quay Pedestrian and Cyclist Bridge, Perth

Client:
Metropolitan Redevelopment Authority (MRA)

Arup's scope of services:
Architecture, artistic and lighting design, bridge, civil, structural, electrical, vibration and wind engineering, geotechnics, materials and Building Code of Australia compliance

Award:
The Institution of Structural Engineers Structural Awards 2016 - Award for Pedestrian Bridges

Engineers Australia Engineering Excellence Awards 2016

Australian Steel Institute Steelwork Excellence Award 2016

Perth's Swan River waterfront was a city promenade and leisure space during the 19th century. However, as the city grew, roads, land reclamation and new high-rise buildings started to separate the river from the city. To re-connect the river back to the city and revitalise central Perth, the Elizabeth Quay development project was initiated by the government. A distinctive, dual-arched bridge for pedestrians and cyclists – Elizabeth Quay Pedestrian and Cyclist Bridge – forms the heart of this development project and Arup was engaged as lead consultant to provide the multidisciplinary services from concept design through to construction completion.

© Jacaranda Photography

The 'S' form of the 110m long deck provides pedestrians and cyclists using the bridge with dynamic and changing views of both river and city

Challenges

The design presented three core challenges in response to the client's aesthetic and functional briefs. First, its design was to be simple, iconic and transparent; cognisant of the outstanding potential to frame exciting views of the city, the river and South Perth. Second, the bridge must allow public ferries to pass safely beneath. Third, the bridge must have a minimum clear width of 5m to enable pedestrians and cyclists to use it easily and pleasurably.

Arup adopted a digital design workflow to respond to the three challenges and it proved to be pivotal in the successful delivery of the project.

Bridge geometry

Vessels needed clearance under the bridge, while pedestrians needed smooth access across to the island at the end of the bridge. Arup's architectural solution was an 'S' shape bridge deck allowing the length of ramp required to clear the navigation channel.

Arup identified the critical dependence on the required clearance height over the navigational channel; for each 100mm increase in clearance, the bridge length would increase by at least 4.5m and up to 7m. The height of the public ferry was governed by a 1.5m high aerial fixed to the roof of the ferry.

The bridge must have a clear width of 5m for pedestrians and cyclists to use it easily and pleasurably

To reduce the height of the ferries and the necessary clearance, Arup successfully negotiated with the governing and approving bodies for the relocation of this aerial on every ferry. This change not only achieved a significant cost saving for the project but also realised the client's desired aesthetics.

Bridge structure

To echo the 'S' shape of the deck, Arup engineered two leaning arches with 45m spans connecting in the middle and sweeping down towards the water to rest on concrete piers supported on piles socketed into the bedrock.

Arup's architects and engineers worked closely together to parametrically create efficiencies in the arch geometry relative to the bridge deck geometry so to ensure the dramatic inclination of the arches were optimised with the critical structural support they provide to the deck through cables.

Although the bridge balustrades have to be 'transparent', the bridge still needed some level of solidity in order to reduce wind-induced vibrations. Arup's wind engineers reviewed every surface in the bridge to mitigate vibration and overcome potential vortex-shedding issues.

Based on these analyses, Arup justified a bridge deck that was only 250mm deep at the edges. This elegant appearance exceeded the client's aesthetic expectations and is a reflection of the ingenuity of our collective design team.

Digital workflow

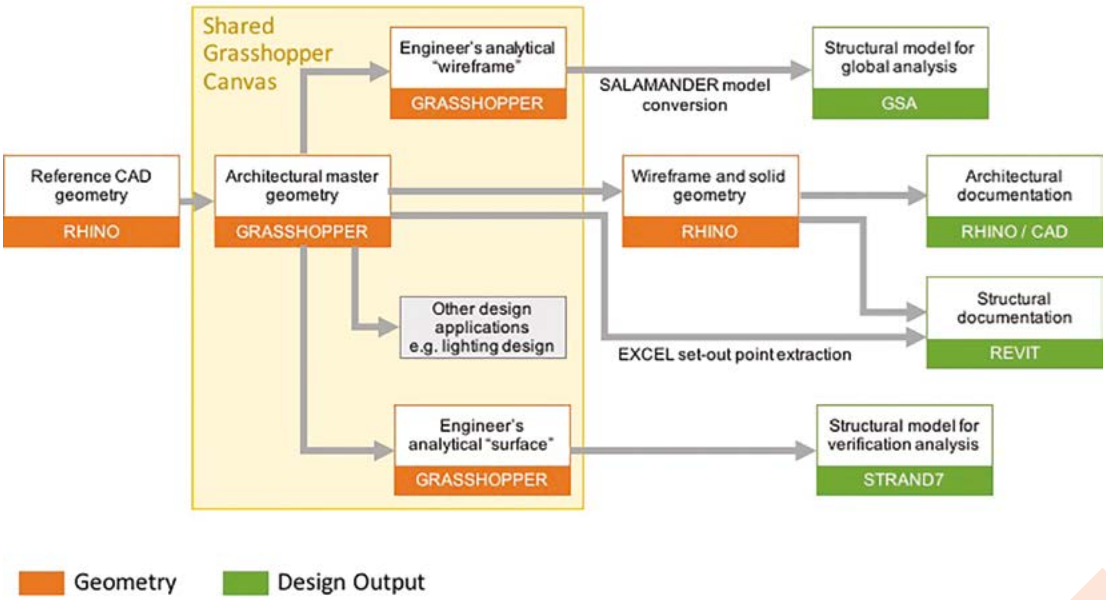
The digital design workflow allowed the parametric script to be widely shared among the design team as well as the fabricators; this optimised the coordination leading to the successful delivery of the project.

The architects first used Rhino and Grasshopper to quickly converge on the architecturally desired and conforming S-shaped bridge design. Working from the same shared Grasshopper canvas, the engineers were able to generate analysis models to assess the structural performance of the bridge form as it developed in concept. These direct digital links optimised and rationalised the profiles of the complex bridge form in a very short time-frame.

The geometry was then referenced into Revit and Strand7 for structural documentation production and final structural verification.

This holistic digital workflow approach meant that direct relationships were made to the shared geometry between the design team via their linked script so that architectural and structural refinements could occur in parallel without losing element-to-element connectivity. In addition, this workflow helped: generally, to ensure accuracy and flexibility; money-wise, steel tonnage reduced leading to direct savings for the client; aesthetically, significant reduction in the depth of the bridge deck.

The design of the Elizabeth Quay Pedestrian and Cyclist Bridge overcame every technical challenge while ensuring the bridge's visual appeal was at the forefront of the design.



Digital workflow diagram

Getting to grips with emerging technology

The Technology Timeline 2017 showcases 20 emerging and future technologies with a high disruption potential for the engineering and construction sector.

There is no doubt that the rapid evolution of new technology will bring change to the world, but how will the engineering and construction sector be affected? Which technologies have a bigger impact on us? When will this impact take place?

To answer these questions, Arup's Foresight team and subject matter experts across Arup are working together to develop 'The Technology Timeline 2017' report with an aim to enable a wide audience to anticipate the implications these disruptors could have on us.

While the scale and maturity rate at which technological change will happen is fraught with complexity and uncertainty, professional judgment and reasonable assumptions are made about the pace of change and likely impacts across the breadth of the sector.

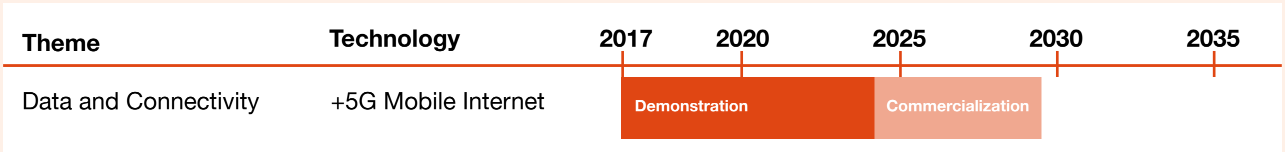
Download the report
http://www.driversofchange.com/projects/technology-timeline-2017

This interactive report looks at the attributes and possible applications for 20 identified technologies.

The 20 technologies examined in the report are:			
Automation and robotics	Augmented intelligence Autonomous vehicles Passenger drones	Energy and resources	Foam batteries Fusion reactors Transparent solar panels Pollution digesters
Data and connectivity	5G mobile internet Blockchain Bluetooth 5.0 Li-fi Quantum computing Smart dust	Interfaces and visualisation	Deep mapping Mixed reality Multi-sensory interfaces
		Materials	Nanomaterials High-performance materials Programmable materials Bio-based materials

A timeline offering insight into the likely timescales in terms of technology readiness levels is presented for each technology. Brief introduction of the technology, latest development and application references are also presented.

The impact of **5G mobile internet**, opportunity or threats?



Market trend for mobile data:

5G mobile internet

Global mobile data use has grown exponentially in recent years, increasing by 74% alone in 2015. Next-generation mobile internet, called 5G, is expected to handle much more data, connect more devices, reduce latency and provide increased network reliability.

Impact to the construction industry

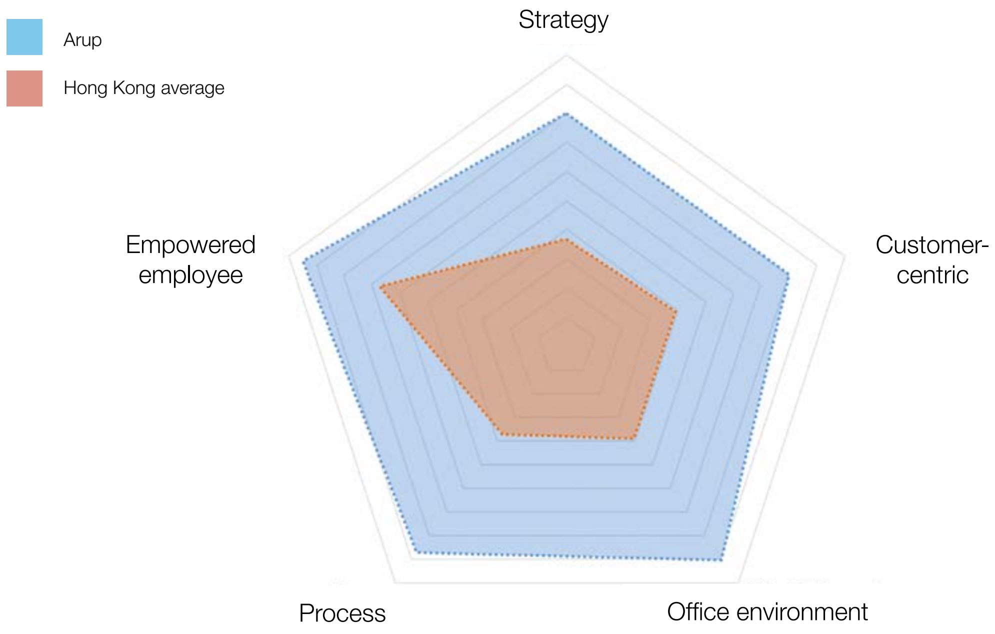
5G is being seen as a transformational technology that will likely have a major impact on our sector and a wide range of industries including energy, transport and healthcare. It will be a key enabler for the Internet of Things as well as for the development of artificial intelligence.

The Foresight team is Arup's internal think-tank and consultancy which focuses on the future of the built environment and society at large. It developed the concept of 'foresight by design', which uses innovative design tools and techniques in order to bring new ideas to life and to engage all stakeholders in meaningful conversations about change. The 'Emerging Technology Timeline 2017' report and other Foresight tools and publications are available at **www.driversofchange.com**.

Arup scores 'excellent' on innovative efficiency

Innovation is identified as the driving force for value creation and future survival of an organisation. There is a growing awareness that competitive advantage and sustainability are directly linked to the innovation capability of organisations.

Arup's score and the Hong Kong average score in the five dimensions of EIECI



Arup's Hong Kong office recently participated in the first Fuji Xerox Hong Kong 'Enterprise Innovative Efficiency Capability Index' (EIECI) and we are very pleased to report that we scored 'excellent' according to their scoring system.

The research, conducted by the Knowledge Management and Innovation Research Centre of The Hong Kong Polytechnic University, surveyed 100 respondents from Hong Kong companies of various sizes in six industries, including financial services, trading and logistics, tourism and professional services.

The research measured a company's innovation performance in five dimensions – strategy, customer-centric, office environment, process and empowered employee – along with their respective aspects.

The innovative efficiency score for Arup was 86, while the average of all participating companies was at 42.24. The top 2% of the participants, including Arup, scored 'excellent'.

According to the reviewers Arup particularly exhibited strengths in 'office environment' and 'empowered employee' dimensions. Our open area in the office allows our staff to interact and brainstorm ideas. In addition, Arup University empowers staff to explore business trends, inspire new ideas and share new knowledge while also providing training.

To accelerate the generation of new ideas, Arup actively creates partnerships with different companies so to build up an innovation ecosystem. We have partners in diverse areas including: developers, universities, emerging technology providers, think tanks, start-ups and giant technology providers. These collaborations allow Arup to tap into the knowledge and insights of our partners and jointly we are able to create some remarkable outcomes.

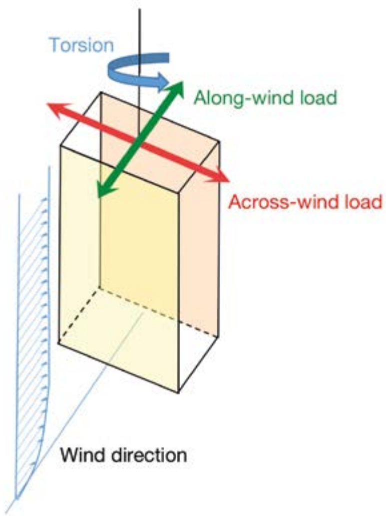
Arup's Creative Space in the Hong Kong office allows staff to interact and brainstorm ideas

To better achieve the structural ambition: Wind loads on tall rectangular buildings

The development of building technology and the increasing number of architecturally driven designs involving more free form geometric structures has led to taller, more slender, lighter and more aerodynamically sensitive building structures. It is, however, noted that the current design codes and standards cannot cover all building geometries and, in a few situations, these codes of practice could lead to an unsafe result. Arup has, therefore, carried out a study to assess the applicability of the design codes and standards and proposed methods to better estimate the wind loads for safer design. This study focuses on the across-wind load on rectangular tall buildings.

Across-wind response assessment

Structural design of tall buildings is mostly driven by wind-induced vibrations, drifts and forces, including the along-wind load, across-wind load and torsional wind load.



■ Definition of across-wind and along-wind loads

Across-wind is normally induced by vortex shedding, which occurs when wind hits a structure, causing vortices to form alternately from opposite sides of the structure giving rise to a fluctuating load and movement perpendicular to the wind direction.

Eurocode 1 EN 1991-1-4 (Eurocode 1) is often used in tall building design; it provides guidance on the determination of natural wind actions in the structural design of buildings and other civil engineering works, including those with heights up to 200m.

Along-wind loads of rectangular tall buildings can be calculated using force coefficients in Eurocode 1 when the slenderness ratio (building height/width) is less than 5. For across-wind loads, several criteria and guidelines in Eurocode 1 may be used to assess whether vortex shedding needs to be considered. However, these guidelines cannot provide the equivalent across-wind load of tall buildings at different design wind speeds. For slender buildings subject to high typhoon design speeds, a common occurrence in East Asia, a safer design method is needed.

In Arup's case study, the methods from four international wind load codes — Chinese code (GB), Australian/New Zealand code (AS/NZS), Canadian code (NBC) and Japanese code (AIJ) — were used to evaluate the across-wind shear forces and moments on rectangular tall buildings.

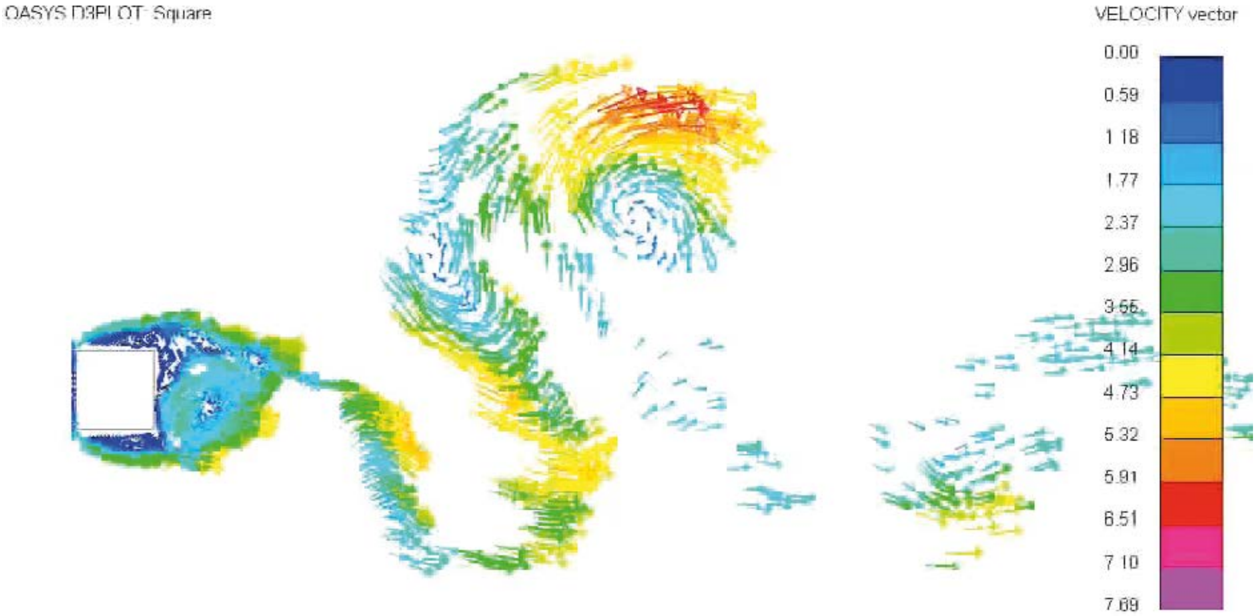
Four typical tall buildings were considered (see table). All are typical tall buildings and within the 200m limit of Eurocode 1.

The basic mean wind pressure for the analysis was from 0.2kPa to 1kPa, to cover most buildings that might use Eurocode 1. The overall base shear forces and base moments demonstrated the same overall trends between along-wind responses and, as the basic wind pressures increased, the across-wind responses increased more strongly compared to the along-wind loads. The results for buildings No. 2 and No. 3 indicated that when the design basic wind pressure is higher than 0.3kPa, the across-wind loads may become higher than the along-wind loads. The sensitivities to the natural period of building and the structural damping ratio are also assessed to identify critical situations.

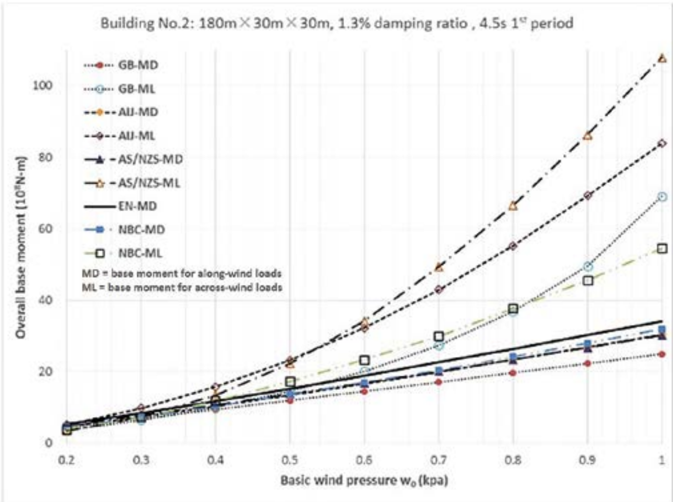
Case study on rectangular tall buildings

Case	Structure height, H (m)	Structure breadth, B (m)	Depth of breadth, D (m)	Side ratio (D/B)
No. 1	100	25	25	1.0
No. 2	180	30	30	1.0
No. 3	180	30	60	2.0
No. 4	180	60	30	0.5

*Case No. 3 and Case No. 4 are the same building rotated by 90 degrees.



CFD simulation (discrete vortex method) showing vortices being shed around the corners of a rectangular building



Overall wind loads of building No.2 in different wind pressure

Based on the case study, it was found that across-wind loads will be the critical wind load direction for more slender buildings. Calculation of the overall across-wind base moment will be recommended for a safer design, if:

1. The building is taller than 100m; side ratio D/B < 1.2 and H/B > 4
2. The fundamental period is larger than 5s and the damping ratio is less than 1.3%.

Details of the case study is published in Issue 3, Volume 95, The Structural Engineer.

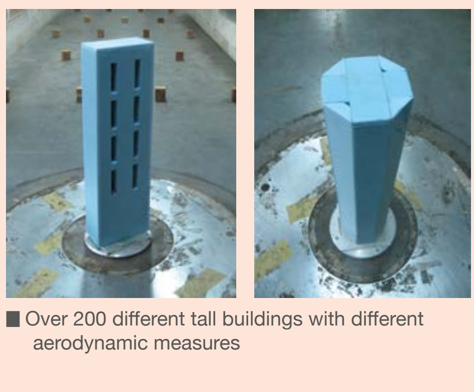
Structural damping	1st period	Mean mass density in each floor
1.3%	2.2s	1.3 t/m²
1.3%	4.5s	1.1 t/m²
1.3%	3.5s (along-wind)/4.5s (across-wind)	1.1 t/m²
1.3%	4.5s (along-wind)/3.5s (across-wind)	1.1 t/m²

Database for more accurate and quicker wind load estimation

Arup is also working on a tall building wind load database for quick desktop study and aerodynamic optimisation.

Based on the raw wind tunnel test data and Arup design experience, our team re-analysed all the raw data to provide the empirical formulae for estimating the along-, across- and torsional wind loads, and the associated accelerations for normal tall rectangular buildings, and correction factors for different aerodynamic measures.

Over 200 different tall buildings with different aerodynamic measures, such as corner modifications, openings and tapering were studied. 71 physical models of rectangular section tall buildings with different side ratio and slenderness ratio under different categories of terrain roughness are also covered. Thus, the wind load database can provide a better estimation of across and torsional wind loads and provide a basis for future revision of international wind codes.



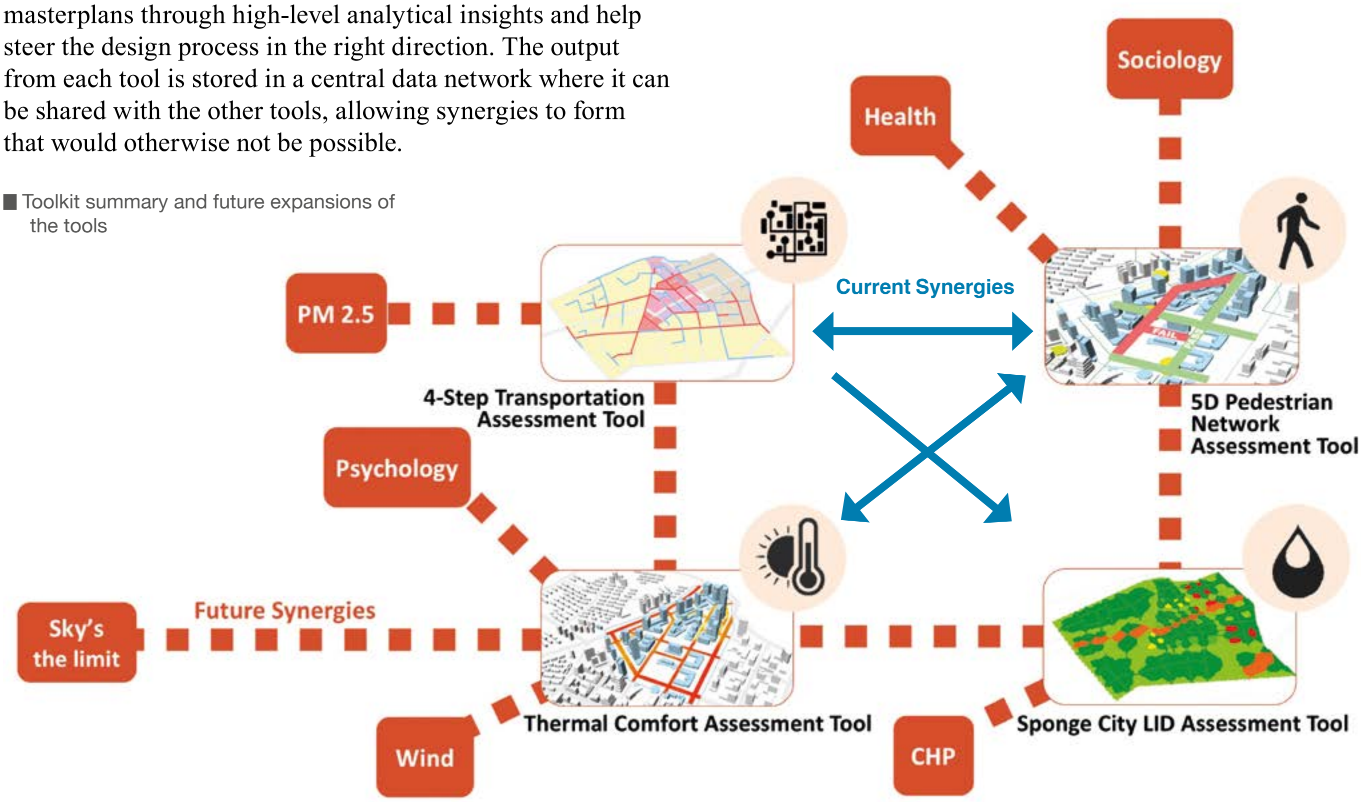
© Forrest Zhang

Over 200 different tall buildings with different aerodynamic measures

Building digital bridges: A toolkit to inform and enrich conceptual masterplanning

Arup has developed a toolkit to guide the design of conceptual masterplans through high-level analytical insights and help steer the design process in the right direction. The output from each tool is stored in a central data network where it can be shared with the other tools, allowing synergies to form that would otherwise not be possible.

■ Toolkit summary and future expansions of the tools



The Parametric MasterPlanning Toolkit consists of four sub-tools covering transportation, pedestrian movement, thermal comfort and low-impact development (or 'Sponge City' as coined in mainland China). The toolkit's role fills the gap between conceptual urban planning and the more rigorous and technically exacting demands of regulatory and near-construction phases of a project. This allows designers to evaluate, refine and gauge the impact of changes across multiple considerations in parallel, informing the design process. The tools operate within one software ecosystem (Rhino and Grasshopper plugin), and there is no need to run the design through several programs in order to see results.

The code of the toolkit has over 5,000 lines of in-house, custom-scripted Python and a small amount of open-source kernels. New features can be added to the core set of tools to include new disciplines and outputs at any time; the toolkit is therefore constantly evolving.

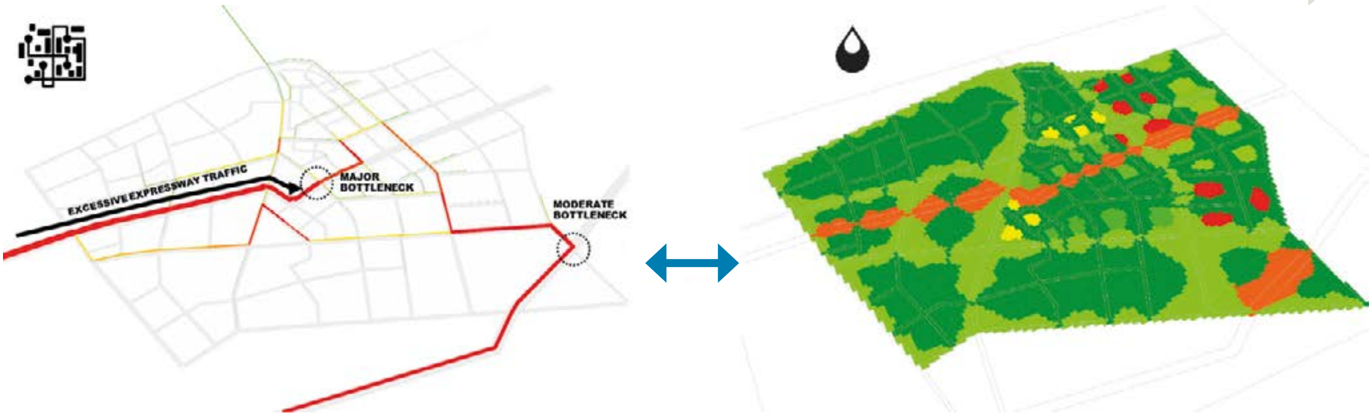
The tools share their output data in all feasible ways, thus new insights can be created that are not possible with most separate, specialised tools. For example, by feeding in results from the Transportation sub-tool, soil contamination levels can rise or fall; and by increasing pedestrian accessibility and reducing traffic volumes we can thereby decrease soil contamination and visually illustrate this change.

Additionally, the tools offer new functionality which cannot be found in existing software. For example, the Pedestrian tool translates five 'D' dimensions of pedestrian movement — density, diversity, design, destination and distance — into a spatial context.

The toolkit also has the function to automatically generate 3D massing of a district or city based on general and location-specific principles.

The sub-tools

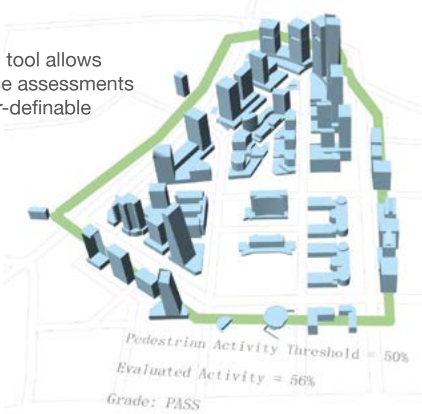
Transportation - Aims to steer the initial network design of conceptual masterplans by providing insights into general traffic flow patterns resulting from road network, public transportation, open space, land use and floor area ratio (FAR) inputs. Level-of-service assessments are provided



The Transportation tool has an option to help inform the Sponge City's soil contamination feature

based on changes to land use, FAR and network changes to show the impact on traffic flow.

Pedestrian - Examines whether the design scheme is conducive to high walk rates and public transit usage by measuring design performance among the five 'D' dimensions : Density, Diversity, Destination and Distance. The tool can work as a standalone process or as a branch from the Transportation tool results.



The pedestrian tool allows level-of-service assessments based on user-definable thresholds

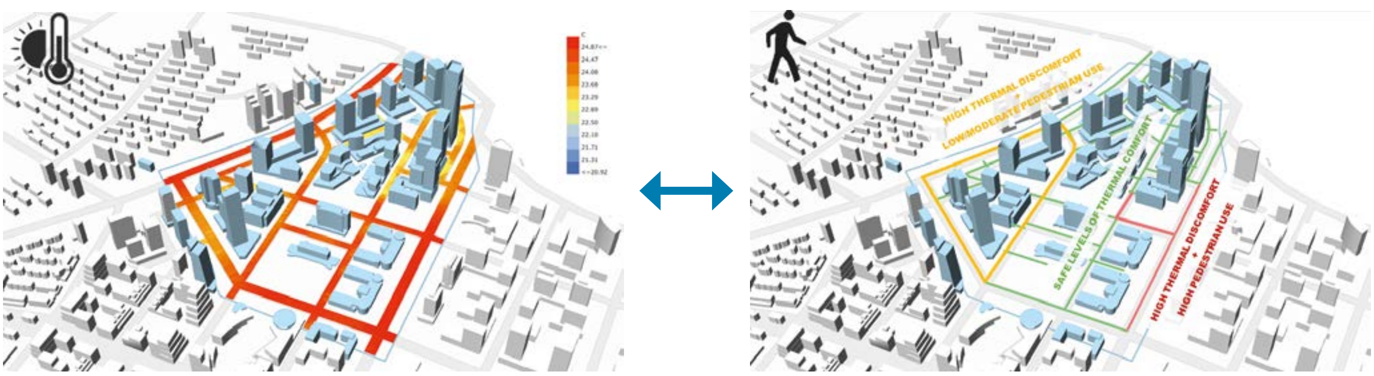
Thermal comfort - Utilises specific sustainability indices, EnergyPlus Weather data and open-source statistical kernels to interpret the impact of thermal comfort on the designed environment, allowing designers to make informed changes to open space networks and building massing. When combined with the Transportation tool, it can evaluate comfort levels based on activity type.

Sponge city design - Facilitates proper Sponge City plot and network planning. Performance is measured by the effects on stormwater runoff of low impact development (LID) elements per plot and based on super- and supra-plot groundwater contamination levels extrapolated from land use characteristics and the presence of LID elements.

Sponge City tool per-plot soil contamination (left) and aggregate contamination (right) levels

This Parametric MasterPlanning Toolkit brings Arup teams together by providing a platform for exchange of knowledge, creating a central hub for data and principles that can be expanded and developed with time.

It also allows designers to gain insights into their designs that were previously out of reach due to the lack of a clarified workflow, access to specialised software, and a general lack of the availability of tools integrating multiple disciplines.



The thermal comfort tool displays both raw comfort and priority illustrations, interfacing with the Pedestrian tool

Tackling the climate challenge: Risk assessment tool for Yangtze River Delta Region

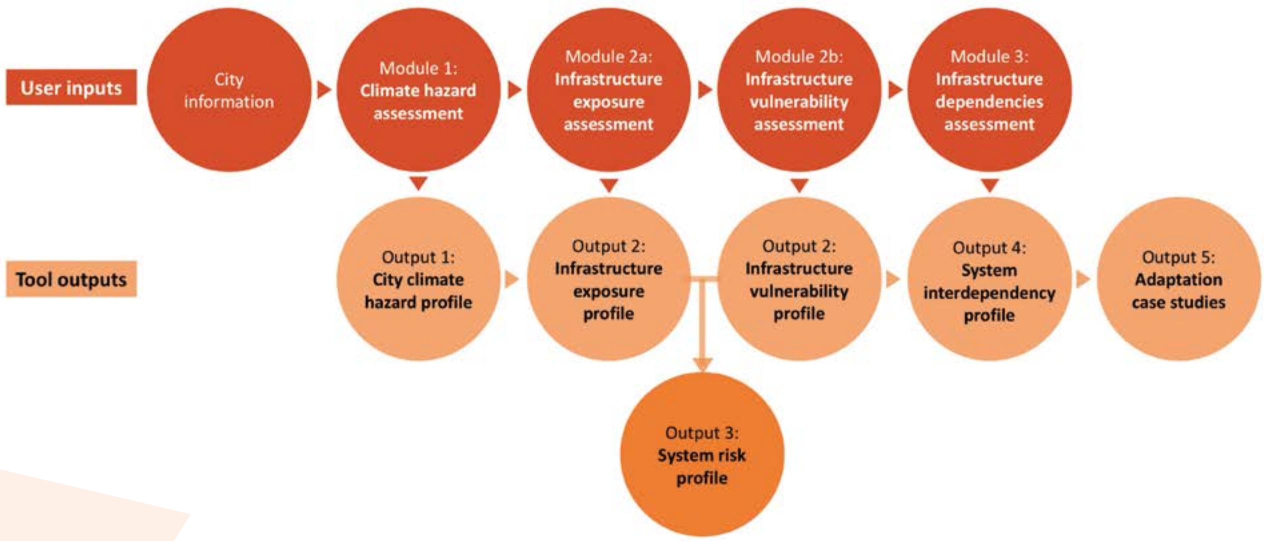
The city cluster in the Yangtze River Delta is China's most economically developed and urbanised area and Shanghai, at its heart, links 26 cities. Extreme weather can lead to structural damage to city infrastructure, consequently leading to a domino effect between systems. Hence, there is a need to better understand the climate challenges and to strengthen policy coordination across cities for improved preparation and adaptation to climate hazards.

Supported by the UK Foreign & Commonwealth Office's China Prosperity Fund, Arup has developed a climate risk assessment tool to help the Climate Centres in 26 Yangtze Delta cities review their climate hazards and determine the risks. This project is in collaboration with the China Eastern Climate Change Center, Shanghai MET Office and the Climate Centres of Jiangsu and Hangzhou.

Developing the tool

In the field of climate change, Arup has an extensive partnership and research background with government agencies for providing practical strategies to address future. In this study, measures and strategies employed by international cities with similarities to that of the pilot cities in the Yangtze River Delta were used as reference and analogy. Examples of best practice actions are presented as a searchable library of case studies.

Based on our research of climate hazards, Arup created and piloted a simple climate risk assessment tool to identify the key hazard in the Yangtze Delta Region for now and in the future, assessed the likely impact of these hazards and, from this, identified priority areas for infrastructure adaptation action.



How to assess the risk

Basic information about the city population and geography is required to create a list of climate hazards, followed by performing a risk assessment not only at present but also in 30-year and 50-year intervals. Furthermore, with the aid of spatial hazard maps, an infrastructure exposure profile is established which highlights the significance of failure of mitigation measures in relation to service functionality and the proportion of critical assets that is exposed to a particular hazard. The vulnerability of each infrastructure is also reviewed based on how they were planned, designed, operated and maintained. This is achieved by displaying the climate hazard to which the asset is most highly exposed and, from this, identifying priority areas for adaptation action.

The assessment tool is completed by highlighting the interdependencies between infrastructure systems and, when combined with system risk outputs, the user is able to understand which systems are most at risk and how that might in turn affect other systems.

The tool is quick to complete, and provides results automatically. Its graphical outputs are highly visual and simple to comprehend, making the results easy to communicate with decision makers.

Pilot application in three cities

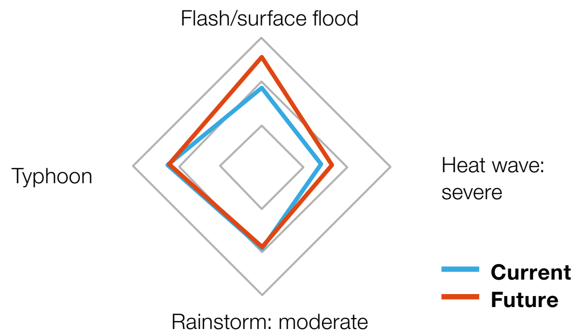
Using this tool, the Eastern China Climate Change Center and Arup conducted the climate risk assessment on the key infrastructure in the Yangtze River Delta together, using Shanghai, Hangzhou and Zhenjiang as the three pilot cities. More than 20 experts from their infrastructure departments participated in the risk assessment. It was found that in terms of climate risk, infrastructure exposure and vulnerability experienced by the city cluster vary. However, all cities are susceptible to heatwaves, waterlogging and rainstorms both now and in the future. The city infrastructure assets are also highly dependent so it is crucial to ensure that all infrastructure is considered in the design and operation phases to which climate risks are taken into account so as to prevent knock on effect between systems.

The tool was well received by the cities. The Vice Mayor from the city of Hangzhou provided positive feedback on the analysis results by emphasising the importance of acknowledging infrastructure vulnerability to climate change risks.

The way forward

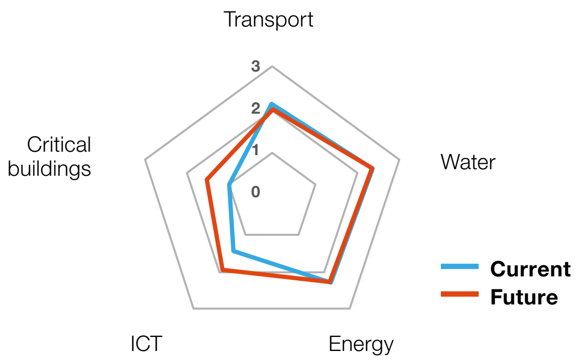
This risk assessment tool enables city governments to identify priority areas for improved preparation and adaptation to climate hazards. Arup hopes that the tool can help speed up the development of the simplified climate model so to enhance city competence in responding to urban climate change problems.

Top 4 Hazards to which city assets are most exposed



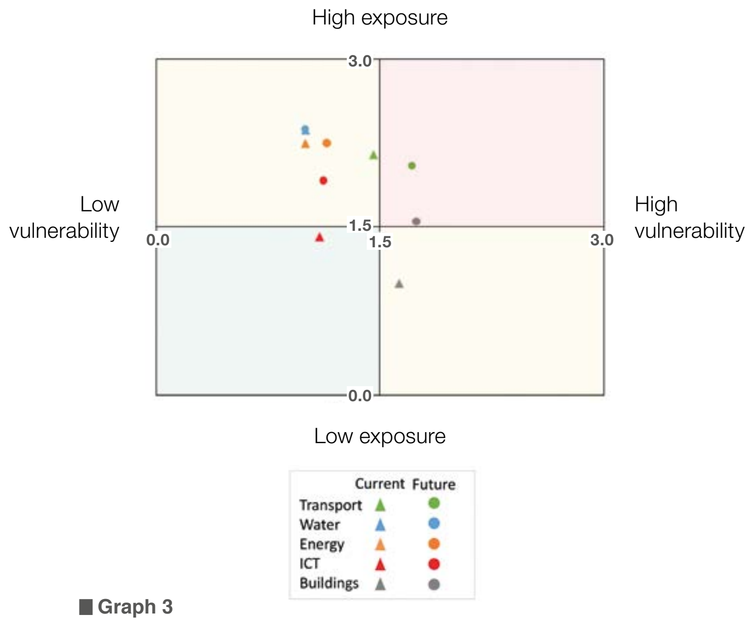
Graph 1
Shanghai is highly exposed to rainstorm, typhoon, surface flood and heatwave; impact from rainstorm and heatwave will be more severe in the future

Cumulative system exposure of infrastructure



Graph 2
Among the five infrastructures being considered, water, transport and energy are at high risk; however, risk on ICT and critical buildings will gradually increase

Risk assessment of critical infrastructure



Graph 3
Most infrastructures are in the top left quarter; this means that even though they are exposed to high risk, they have low vulnerability, mainly because of their proper design and maintenance

‘Experience’ our design: ArupREAL AR & VR Bootcamp

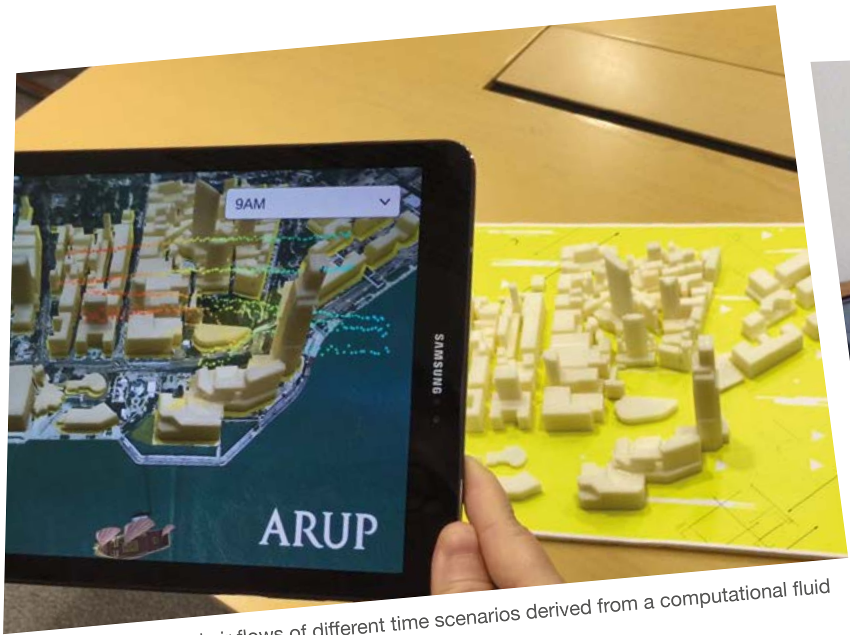
Immersive visualisation technologies such like virtual reality (VR), augmented reality (AR) and mixed reality (MR) (simplified as ‘AR/VR’ here) have become more and more accessible for the consumer market. This has offered huge potential for the AEC industry to apply these emerging technologies to our projects and bring new or expanded values to our clients/users.

Arup, being the engineer and designer of the projects, we can now demonstrate our analytical data and simulation results in the virtual world so to facilitate the communication and decision-making with our clients or among the design teams. This greatly minimises the gaps of understanding technical drawings, diagrams and jargon, and thus democratises the process of built environment development.

Spearheading in exploring and promoting digital technologies, East Asia Arup University (EA AU) provides technical support and training on AR/VR to incubate our staff with the necessary skills – so to speed up skills provision of mastering these new technologies and scale up its impacts.

ArupREAL

Over the past two years, the EA AU team has developed various applications with AR/VR technologies. Collectively Arup named it ‘ArupREAL’ to house all these immersive visualisation applications created in Arup.



Inspecting animated air flows of different time scenarios derived from a computational fluid dynamics microclimate simulation with using AR

Reviewing structural design interactively with using AR

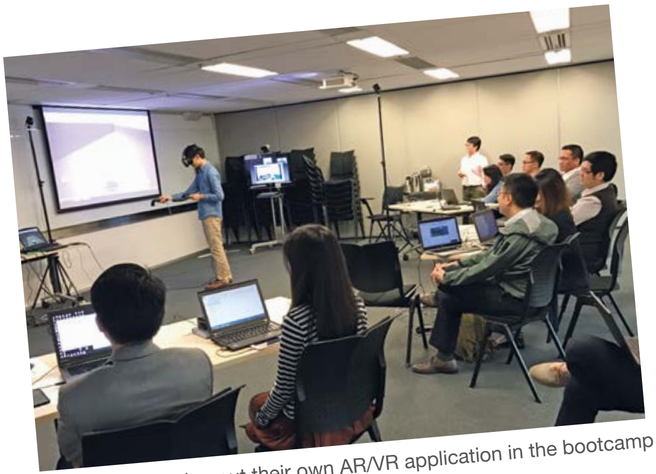
ArupREAL bootcamp

‘Bootcamp’ is a new training format that we found it can not only very effectively train up digital practitioners but also engage them and cultivate an active skills community after the event completed. EA AU has organised the 1-day ArupREAL bootcamp that consists of training, coaching, and a hands-on AR/VR application development exercise. Participants are brought to fly through a highly polished virtual reality experiences.

Apart from attending a full-day classroom training, the participants were requested to work in teams to produce AR/VR applications – with using their own project data/ models in various formats such like Rhino, Revit, ETABS, MassMotion, SketchUp etc, and the various tools that they learnt during the Bootcamp, to run on various AR/ VR devices such like mobile phone, HoloLens, VIVE and Oculus, in two weeks.

The end of the bootcamp is an exciting competition event with cash prizes. The judges were amazed by the progress the teams managed to push to in such a short timeframe and the creativity they could realise through cross-disciplinary applications. More importantly, the teams clearly demonstrated how 'immersive visualisation' can be applied to Arup projects and bring value to our clients with real multidisciplinary models and real business cases, and implemented in a cost-effective manner.

Demonstration the application to the judges in the final competition event



Colleagues trying out their own AR/VR application in the bootcamp

Put learning in action

With the practical experience learnt from the bootcamp, AR/VR has already been implemented in many project cases by the newly trained practitioners. It helps to create a holistic view in the design review stage, as well as differentiate Arup in the bidding process.

Support AR/VR development

In order to accelerate the learning cycle, AU also developed a comprehensive production guideline and standardised templates which help increase the efficiency for AR/VR development. Necessary hardware and software infrastructure are also in place to provide an advanced platform for Arup staff to adopt the AR/VR technology in projects. Talk to Arup project teams or Arup University to see how the technology can be applied in your project.

AU Digital Incubation Series

The ArupREAL bootcamp is part of the Arup University Digital Incubation Series for our EA staff. More digital trainings such as a 'datacamp' which looks at extending the use of project datasets with programming and data analytics skills, will be rolled out soon. This particular series aims to upskill our designers and engineers with the latest digital technologies, so that we can deliver our design in a more creative and efficient manner that ultimately benefit our projects and clients.

Panorama VR image taken in the bootcamp

The InnoVision Lecture Series is a platform allowing Arup Fellows to give our clients and the general public a fresh insight into the built environment

Arup Fellows:
Leading the industry from within

The Arup Fellowship celebrates creative and technical excellence which allows us to find better ways to realise our clients' vision. Arup Fellows inspire our next generation of design and technical leaders and drive innovative thinking across the industry and society at large.

Instituted in 2003, the Fellowship provides the highest recognition of the unique value each Fellow brings to Arup and asks them to champion design and technical excellence across the firm's global activities.

Apart from outstanding contribution to the quality of work in their own projects, internal and external recognitions are also important criteria for an Arup Fellow.

■ Sharing experience with professional institution members by Arup Fellow

■ Sharing experience in 'Fellows Film' - talking about their career, what has inspired them and some of the projects they have worked on

Being inspirational and influential are required competences in the work environment. Clients and colleagues can always turn to Arup Fellows when seeking solutions to problems that need world-class perception and experience. Fellows are the people who will inspire Arup and the industry with their knowledge, style and innovative ideas.

Knowledge sharing is a crucial mission for our Fellows and they receive internal funds to support their teaching and spreading of knowledge. They are frequently asked to conduct project reviews, deliver lectures and participate in early stage design workshops. Not limiting their sharing within Arup, our Fellows also conduct public lectures and sharing sessions, creating an interactive experience sharing platform for industry practitioners.

Stay tuned for our up-coming lectures to be given by Arup Fellows.

39 Arup Fellows have been recognised and they are all actively applying their expertise on projects. To see who they are, please visit https://www.arup.com/our-firm/arup-fellows.

Wilfred Lau

From the established to the emerging

Wilfred Lau, Arup's East Asia consulting business leader is the first from the consulting sector in the region to be named as Arup Fellow, the highest designation within Arup for technical achievements.

From an unconventional path

Wilfred indeed got a few 'firsts'. A civil engineer by training, he was the first overseas graduate hired by the Hong Kong government and the first locally qualified engineer employed by Arup in Hong Kong in 1981.

Wilfred still remembers many interesting projects from those early days and amongst them is the accommodation for the 5th Battalion at Sai Kong. "Quite a few interesting problems were overcome on that project, including a Fengshui Hill to soothe the concern of nearby villagers," he recalls. "We made small changes here and there which resulted in much better outcomes. This struck me with the big difference that small improvements can make."

After that, he emigrated to Canada, where at one time he ran an independent architectural and consulting subsidiary for a developer as Vice President of Development. He returned to Hong Kong to develop toll roads and deep sea ports in mainland China and rejoined Arup in the late 1990s.

Such unique experience contributed greatly to his deeper understanding of clients' needs from both the public and private sectors and his growing interest in exploring the new and the untapped.

Spearheading into the new

Upon rejoining Arup, Wilfred started to build up the Transport Consulting group and later championed the consulting practice in East Asia, as part of the firm's initiative to sustain its continued success by broadening its skills beyond core capabilities. "Developing new businesses is what I enjoy most," admits Wilfred, "but it's also extremely challenging and requires total dedication."

The first two years were tough but the team soon cemented its reputation with signature projects like the intelligent transport system for Route 8 in Hong Kong. "Route 8 consists of roads, bridges, viaducts and tunnels, leading to a variety of requirements and regulations. That was quite a learning experience for us. Finally, we proposed an integrated traffic control and surveillance system (TCSS) to be managed under one control centre to minimise cost. Our solution also allows ease of future expansion and maintenance," he says proudly.

© John Nye

■ Our solutions for the Route 8 TCSS significantly reduced the potential technical complexities as well as construction and operation costs

The transport consulting expertise also made Wilfred embark on the venture into Vietnam in 1998 with his team providing advice to investors who built industrial parks there. Later the team worked with the World Bank to improve the transport in Ho Chi Minh City, a strategic project that pushed us into a new market and opened a world of new opportunities. With the growing business in the country Wilfred helped formally establish an office in Ho Chi Minh City in 2008.

■ Meeting high level government officials in Vietnam

Also that year, Wilfred decided to set up the Urban Design and Planning team in Hong Kong eyeing the urbanisation opportunities across East Asia. A series of high profile projects, such as Sha Tau Kok, Lau Fau Shan and Taoyuan Aerotropolis, helped increase Arup's sphere of influence not only at the technical level but also at the policy level, from Hong Kong to the rest of East Asia.

Smart Green Resilient

Along the journey, Wilfred and his planning team developed a new approach to urban planning – the Smart Green Resilient (SGR) concept. It is a comprehensive approach that systematically examines non-tangible and service systems, such as governance and wellbeing, and considers their interaction with physical and tangible systems like infrastructure and waste.

"This started with the Ninh Thuan project in Vietnam which brought to our attention that the long-established methods for urban development – under a masterplanning approach with a focus on spatial land-use and economics – would be inadequate to meet future challenges," he reflects.

Evolution of the SGR concept

Integrated planning strategy for Ninh Thuan Province, Vietnam

Lok Ma Chau Loop, Hong Kong

Taoyuan Aerotropolis Development Strategy, Taiwan

New Territories North development, Hong Kong

The SGR book

The SGR book launching event

The philosophy was further developed in the Lok Ma Chau Loop project in Hong Kong before it matured and enabled the Taoyuan Aerotropolis project in Taiwan. “Compared to traditional approaches, SGR thinking can realise the full social and economic potential of an area; it links smart city principles, sustainable development and resilience from the people’s perspective to maximise available resources,” Wilfred explains.

The pioneering approach is best illustrated in the planning study for Hong Kong’s New Territories North development. “In this project, we optimised the SGR concept and many ideas we proposed for this project have now been widely considered as pragmatic solutions locally. These include moving some of the brownfield operations into multi-storey buildings to release the currently occupied land for other uses” he says.

The SGR vision is fully presented in his dedicated book and the holistic thinking behind has been well received. Wilfred is glad to see that SGR has been adopted by the Hong Kong government and is being developed at different policy and operational levels. “The Hong Kong

■ Wilfred and his team in a brainstorming meeting

■ Wilfred at 'A moment with a Leader' casual gathering series with young engineers

2030+ Planning Vision and Strategy is built upon a smart green resilient city strategy to achieve a sustainable and future-proofed city."

Challenging the established

Wilfred takes great pride in SGR as it perfectly fits into his idea of the best consulting solution – being relevant, business-enhancing and future-proofing. "The fact that SGR has been adopted as Hong Kong's strategy to guide its development transcending 2030 helps us make the transformative step to be a strategic advisor in cities in this part of the world. This will further bolster our cities business and enhance Arup's image as a thought leader," he says. Now he's already looking for the next breakthrough.

"Technological development is driving people's behavioural changes, which in turn is disrupting business models. The future depends on how we leverage changing behaviours to innovate our business model and grow the business," he points out.

Now the focus areas of the firm's consulting business include digital services and management consulting – advising organisations and governments at all levels to best respond to future opportunities and challenges.

> *"Engineering is, by nature, an art to conform while engineering for the better is a process to challenge. Always ask yourself 'Is this the best way? Is there a better alternative?"*

However, he believes that we must further our understanding of the digital trend to identify the opportunities and turn them into business. "Digital transformation is much more than the digital technology. We have to delve into its impact on our lives, business models and the industrial ecology as well."

"What's equally important," he adds, "we should better understand our clients, from their physical assets to their business operations. By doing so, we can combine our technical depth with strategic commercial thinking that helps clients make stronger connections between strategy and action."

He urges young engineers to establish a solid foundation through rigorous basic training, and then to challenge the established. "Engineering is, by nature, an art to conform while engineering for the better is a process to challenge. Always ask yourself 'Is this the best way? Is there a better alternative?'"

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Goman Ho
and his 'tall' stories

"Humanity's aspiration for height can trace its origins back to the Tower of Babel and this desire will continue to push engineering ingenuity," says Goman Ho, Arup Fellow and Global Tall Buildings Skill Leader.

This Christian designer is the man behind many of the most challenging and innovative skyscrapers in this part of the world. If you stacked his major tall building structures on top of each other they would stand more than 7,000m high.

"God creates and engineers assemble," states Goman, "We engineers make a difference by exploring the endless possibilities of putting things together." He believes that in this way he serves God and also other people, improving their lives with better engineering solutions.

"Everyone has a role to play in God's eye and an engineer's mission is to build churches, in terms of both hardware and software," he says. Perhaps this reveals the destiny that ties him with reaching high – before the 20th century a city's tallest building was always a church or cathedral.

Go-man is the go-to man

Goman joined Arup's Hong Kong office in 1992 after his PhD. His first tall building project in Arup is the 50-storey East Jinjiang Hotel in Shanghai. After that, he spent some time in both London and Detroit offices and returned to Hong Kong in 1995.

This was followed by the Cheung Kong Center, a 283m tall building comprising 62 storeys of office space with six levels of basement. Upon completion in 1999 it was the third tallest building in Hong Kong and top winner of the inaugural HKIE Structural Excellence Awards.

In 2000, Goman started his life of two cities – he flew between Hong Kong and Beijing, handling projects leading up to the 2008 Beijing Olympics and working with Michael Kwok, now Arup's East Asia Region Chair, to

Taking guests on a technical visit at the Bird's Nest in 2006

"We engineers make a difference by exploring the endless possibilities of putting things together."

© Zhou Ruogu Architecture Photography

Cheung Kong Center, Hong Kong

Arup's Beijing quartet – Bird's Nest, Water Cube, Beijing Airport T3 and The National Conventional Centre winning Tien Yow Jeme Civil Engineering Prize 2009, the highest award of its kind in China

establish our presence in the capital city. He flew to Beijing more and more frequently and stayed there longer and longer and finally settling there.

It was an unprecedented journey of success for Arup and also an amazing fast-track of professional development for Goman. He was involved in the most high-profile buildings such as Beijing Capital International Airport Terminal 3, the Bird's Nest, CCTV new headquarters, China World Tower and Beijing South Railway Station.

Among all these, Goman sees the 330m tall China World Tower as his best design solution so far. "To achieve the necessary combination of strength and flexibility, we introduced

Goman's career journey of reaching high

597m
Goldin Finance 117

460m
Landmark 81

330m
China World Tower

528m
China Zun

a 'composite steel plate shear wall' at the base of the tower. This has made a considerable impact on the local industry development as the method was soon incorporated into the Chinese code," he says.

The composite steel plate shear wall soon became a basic requirement for nearly all tall buildings in China, and Goman continued to help Chinese cities reach new heights. These include the 597m tall Goldin Finance 117 in Tianjin which has the tallest structural level in China; and China Zun, Beijing's future tallest building, which, at 528m, sets a new height record in a seismic zone.

In 2012, he returned to Hong Kong and continued to design towers across East Asia constantly breaking records. These include the 460m tall Landmark 81 which tops the skyline of Ho Chi Minh City, a 460m observation tower in Seoul and a 650m tall tower in Central China.

More than 20 years later, Goman, affectionately known as the 'go man' – the man always on the go for tough design reviews, client meetings and various project offices – has risen up as the truly 'go-to man' to solve the unsolvable in tall buildings.

"I believe engineering is an art and will continue to be an art backed by a systematic approach with emerging tools unlocking new possibilities,"

Up is not the only way

"Thank God for all the fantastic tall building jobs," says Goman, "and the wonderful colleagues who are always devoted to finding a better way and doing something better and different!"

He feels especially grateful for two Arupians who have played a pivotal role in his career – Dr Andrew Chan, who encouraged him to rise above a 'normal' structural engineer and research into the cutting-edge at the Advanced Technology Group (now Advanced Technology + Research); and Dr David Vesey who showed him the power of engineering judgment.

"I was just amazed when I saw David come up with the sizing of columns on sight of the drawing board," he says, reflecting on the day when they worked on a 300m tall building in Shenzhen. Many years later, he was also able to work out the sizing of China Zun in a couple of minutes within a small variation from the final value. "It's all about expert judgment which can only come from experience and learning from the right lessons," he says.

Though a well-recognised tall building expert in the industry, Goman reminds us that his interest and reach is far beyond the 'up' dimension. "The deepest structure I've ever designed

■ Bamboo Pavilion at the Zero Carbon Building, Hong Kong

is Cheung Kong Center which has six levels below ground; my longest structure is the 3km Beijing Capital International Airport Terminal 3 and the largest volume building, CCTV headquarters, has a GFA of 450,000m^2 in a single building without movement joints."

Surprisingly enough, his favourite is not one of these urban icons, but the much less known Bamboo Pavilion, a temporary public event space built for the Zero Carbon Building in Hong Kong. It is a 4-storey high long-span bamboo grid-shell structure with a seating capacity of 200 people. The design was initiated by a team of architectural students from the Chinese University of Hong Kong and was further developed by their professor and Goman using latest digital tools to define its final form.

"After so many mega buildings, I find a unique challenge and beauty in this little project – the traditional craftsmanship of bamboo scaffolding construction revived by the modern art of engineering," he says.

The future is pixelated

Looking into the future, Goman believes that the explosion of urban population and limited land available in cities will continue to spur the move to tall buildings. "Over the past few years, we've seen a shift from a mere race for height to the pursuit of post-modern architectural design with complex geometries," he says, admitting that it's hard to predict the often recurring cycle of trends.

"But one thing is for sure," he adds, "that is, big data and evolving technology such as artificial intelligence, virtual reality and machine learning will have a profound impact on the way we design buildings."

He agrees that we must move into design automation to increase productivity if we are to survive the fierce fee competition. "It's important for us to keep a close eye on the latest digital development but with all the software packages running calculations behind the fancy user interfaces we should always remember what our core values are as engineers".

"If we become slaves to computers and lose our fundamental abilities as engineers, we risk producing mundane or even bad designs 'efficiently' and eventually losing our identity."

He urges young engineers to constantly cultivate their engineering judgment and use computers to verify their design. "Engineering judgment is critical when data is limited or no similar examples exist," he points out, "and it becomes vital to creativity and technical innovation."

He also encourages them to learn the ropes and then think "how can I do it better next time". "Only in this way can you advance to the next level and avoid getting stuck as just another skilled labourer."

"I believe engineering is an art and will continue to be an art backed by a systematic approach with emerging tools unlocking new possibilities," he says.