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Building Services as A Force for Achieving Sustainable Vertical Urbanism in China

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Malcolm Laverick is the AECOM China Regional Director responsible for Building Services and has been based in China for five years. He has over 40 years of experience in building services consultancy and is a chartered engineer, a fellow of HKIE and CIBSE and a member of ASHRAE. His extensive list of projects have been completed in Hong Kong, United Kingdom, the Middle East, and now mainland China, where he acts not only as the Regional Director but also as lead Project Director for large multi-disciplinary building engineering teams.

A selection of his experience in tall buildings in Asia includes: AIG Tower, Chater House, and UBS Bank relocation from Exchange Square into IFC 2 in Hong Kong, Asia Square Towers 1 and 2 in Singapore; Shenzhen Kerry Centre, 688 Nanjing West Road in Shanghai; and Google's relocation into the Shanghai World Financial Centre. He is currently the MEP Project Director for a mixed-use development in Chongqing of 475,000 m² floor area, with five towers up to a height of 170 meters, and in Xian, a single tall tower of commercial offices of 130,000 m² floor area, and 200 meters height. Within China, he has led the development of enhanced engineering design, both in terms of the application of BIM and in-built sustainable design.

The introduction of vertical urbanism, with its necessary increase in population density per square kilometer of ground surface area, has a significant impact upon the primary engineering networks and building services required to support such developments. While urban planners promote vertical living as releasing the ground level for green areas and recreational use, the task of concentrating services is still a significant undertaking for consultants. The sizing requirements for the transportation network that brings people laterally to, and then upwards in, the development – which increasingly involves very little exposure to the external environment – is becoming larger, in order to maintain acceptable internal conditions. Rather than view this obligation as a burden, the services designer should consider it an incentive to introduce energy-efficient solutions that are sustainable and adaptable.

The integration of smarter and enhanced construction techniques, in both international and local developments, along with efforts to reduce energy and operational costs, is a national priority in China. Design solutions that were once considered unfeasible in China are now being adopted, and while there remain large sectors of the built environment that follow traditional solutions, the number of more ambitious clients that recognize the benefits of investing in improved performance is growing. From a construction perspective, contractors with a desire to improve and follow the new trends are actively developing their business around such models and growing their teams in order to implement new designs that have been reinforced with highly efficient building services. They will learn quickly from the building services consultants, who are developing these highly efficient strategies and have a stronger role to play in the future.

Responding to End User Requirements: The Building Services Manager's Role

Direct research for optimizing today's workplace

Providing facilities that can foster a healthy

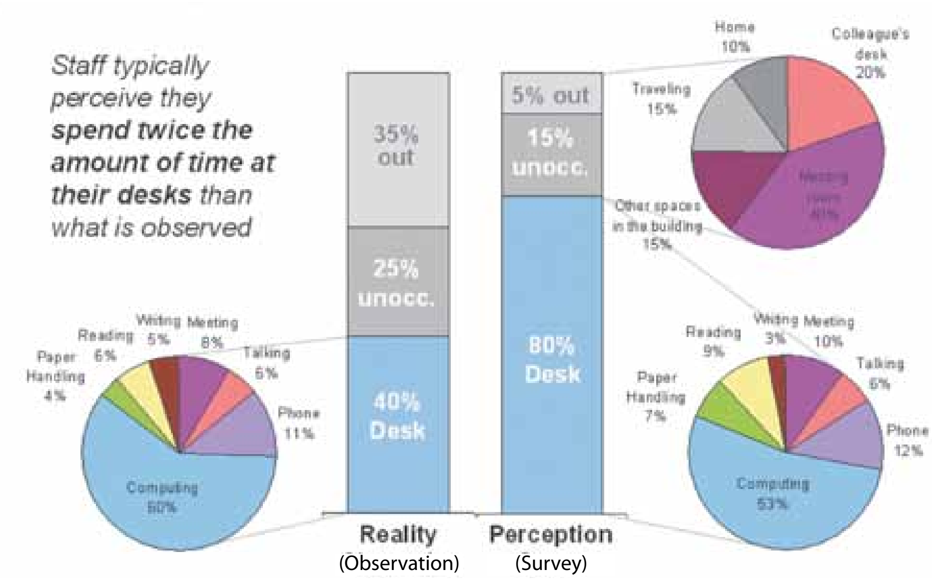


Figure 1. Working patterns – spaces and equipment are valuable assets but under-utilized. Source: AECOM Workplace Management

> “Sustainable solutions that may be common place outside China are sometimes viewed with caution within China. The potential for conflict between the desire to obtain certified products and the client’s wishes to retain the production of such materials within China must be considered.”

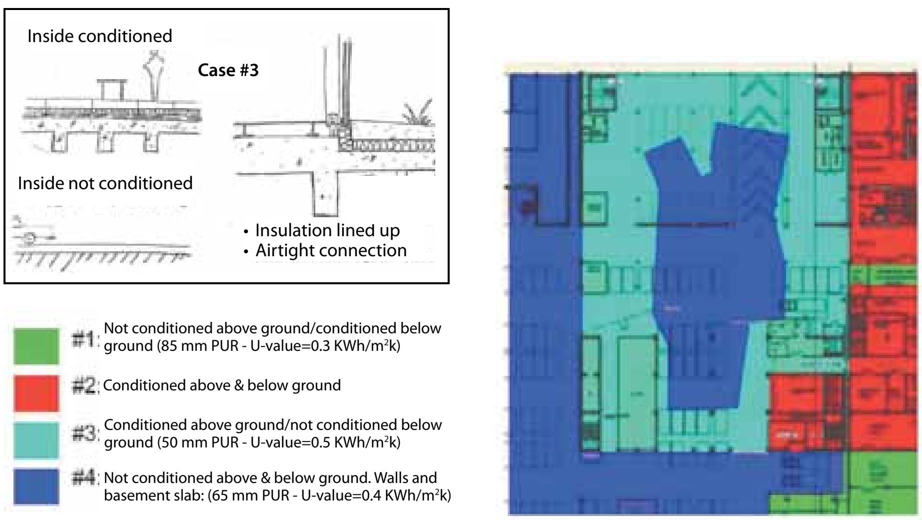


Figure 2. Building envelope - thermal performance.
Source: Multi-story Research and Development Campus Project, Shanghai

environment for people who live and work in vertical developments must be the prime consideration during the design process if such developments are to be sustainable. We must consider longer life cycles for such developments, as these have significant investment cost.

In many cases the design solutions are driven around a known set of parameters documented in such advisory or mandatory standards as ASHRAE or CIBSE (Chartered Institution of Building Services Engineers), the GB (Guo Biao / National Standard), or local Chinese municipal code. This information is essential; however, while it is of course a requirement to follow code in our designs, there is a also need to question the applicability of code mandates to the specific project we are designing.

As an example, the reality of how we work and how we behave in the office environment are often different in reality from what we perceive (see Figure 1). The working pattern as understood by the individual and as measured in reality are quite different. This difference affects the way we create a comfortable environment for the occupants. This is a considered opinion that can only be arrived at through face-to-face communication. Therefore, the design approach has to incorporate such communication. Rather than simply design services “by the book,” the building services engineer has to adopt such best practices when considering the working environment in terms of temperature, humidity, ventilation, and air movement. For the building services engineer, this may require asserting oneself in the design process at an earlier stage and more aggressively than may be the custom, as many still follow the code-mandated approach without engaging in the primary research of client needs.

In today’s modern office designed for the new generation, the provision of sport- and food-related activities are integrated with the normal working environment. The provision of physical activity rooms, showers, kitchens and breakout areas – all of which will have different HVAC requirements – must often be accommodated. Working hours have become much more flexible, which means systems must adjust accordingly. The ability to set automated timings, and use real-time activity sensors and a system of engineering that acknowledges such activities, is essential.

Choosing the envelope

Considering the architectural vision and desire of developers to individually distinguish their properties, the choice of building envelope requires careful consideration (see Figure 2). With the increase in variety of envelope solutions, the interior space systems must adapt intelligently to the envelope and external conditions. Glare, thermal performance, radiant effects, and the impact on the air conditioning vary in terms of

> “Shanghai has a very wide band of external environmental conditions with periods of both very low and very high humidity. Applying radiant cooling installations requires control of both fresh air and the operating temperature of the ceilings and chilled beams.”

exposure, and as such, the envelope design has to adopt appropriate protection. Annual energy costs need to be considered (see Figure 3).

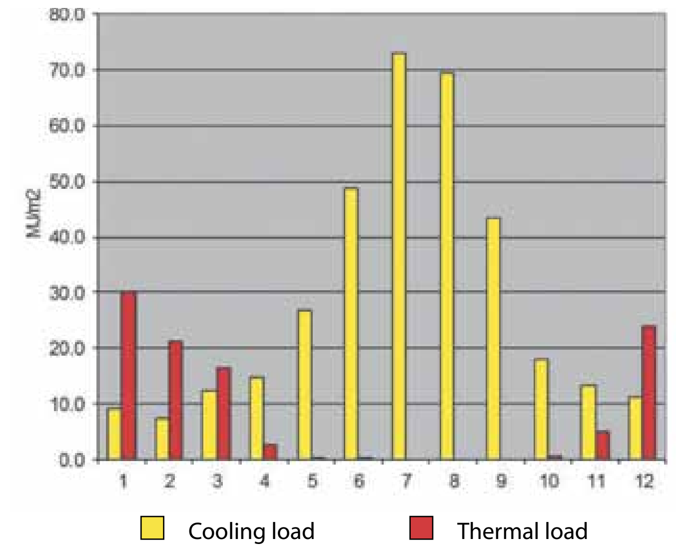
Adjusting vertical transportation

Considering vertical urbanization, the provision of suitable vertical transportation is essential to meet end user need in terms of delivering the service capacity and speed, and as part of the construction and cost considerations, and utilizing the efficiencies of spatial requirements. Advanced technology that can examine these against a known set of design parameters is essential, and providing appropriate advice is essential as well. Figure 4 is an example that shows the base design and two optimized solutions for the Nanning Tower, with the appropriate savings in space, cost, and energy consumption.

From a building owner/operator perspective, the development has to achieve financial control within a planned budget, as well as meet the aspirations of visual impact and operate with installations that are effective, efficient, maintainable, and sustainable.

Choosing a sustainability standard

Registration with one of the sustainable design schemes is now often required by corporate clients. In China, standards embraced include LEED, BREEAM, HKBEAM, and China 1/3 Star. Each of these schemes has



Energy relevant area (m^2)	5,061									Quota (%)			100%
HVAC Loads													
Thermal – Building envelope	MJ/m^2												GJ
Monthly energy balancing	1	2	3	4	5	6	7	8	9	10	11	12	Total	Total
Total gains Qg	20.7	14.0	3.9	-12.1	-26.7	-48.7	-72.9	-69.5	-43.5	-17.4	-8.1	12.9	-247.4	-1,252.0
Heating demand	30.0	21.2	16.4	2.5	0.0	0.0	0.0	0.0	0.0	0.7	5.1	24.0	100.1	506.9
Cooling demand	9.3	7.2	12.5	14.7	26.7	48.7	72.9	69.5	43.5	18.1	132	11.2	347.5	1,758.8

Figure 3. Annual energy performance assessment.
Source: Multi-story Research and Development Campus Project, Shanghai

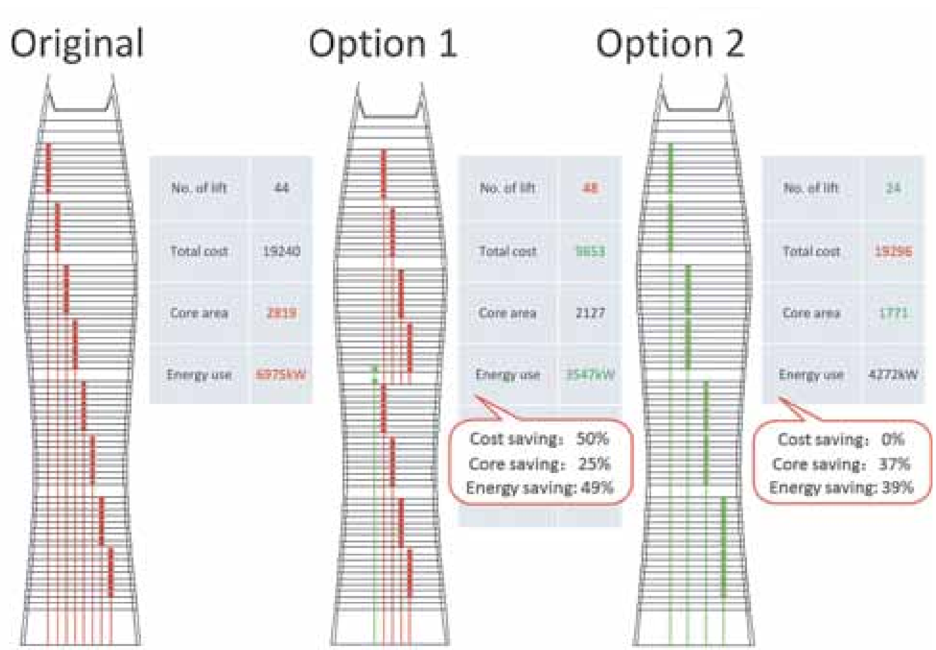


Figure 4. Vertical transportation study for Nanning Tower, Nanning. Source: AECOM VT Team

a different focus, and it's the role of the building services engineer to carefully analyze and assist in the selection of the most appropriate solution for the client. Whichever scheme is adopted, not only must it achieve certification, but it must also achieve demonstrably enhanced performance. This may appear obvious; however, is not a foregone conclusion that "ticked boxes" will turn into measurable results.

Design Coordination

The ability to communicate within the client and design team remains a key component of achieving success for these new designs with strong sustainable features. The desire to have "the best" and most individualistic designs, often requires merging the talents of overseas designers with local knowledge and code interpretation to ensure the design is progressed through a route that will not only be distinctive and innovative, but will also be approved through the China codes. This is particularly relevant in terms of life safety systems, where there is often the need to balance local code with international insurance requirements, such as National Fire Protection Association (NFPA) or Factory Mutual (FM). Sustainable solutions that may be common-place outside China are sometimes viewed with caution within China. The potential for conflict between the desire to obtain certified products and the client's wishes to retain the production of such materials within China must be considered.

Solutions

The ability to develop and coordinate appropriate solutions requires a suitably robust process. Design coordination has been greatly aided by the use of Building Information Modeling (BIM).

BIM has allowed improved space management, with a certainty of obtaining correct ceiling heights with reduced floor-to-floor heights and integrated structural and building services solutions, as well as easing the transfer from drawing to reality (see Figure 5).

The following examples demonstrate how BIM was instrumental to the design of building services, and armed the building services engineer with the ability to provide overall project guidance on a range of high-rise projects in China.

DZL, Shanghai

The DZL high-rise project in Shanghai (see Figure 6).required the floor-to-floor height to be reduced from the original design by 100 millimeters, to 3.9 meters on each floor, a prescription that, factored over the full height of the building, allowed the introduction of one more floor level and increased letting area. External wall area was reduced on each floor, which also reduced the solar gain per floor, while retaining the ceiling height. Translating this change and reviewing all of its implications would have been nearly impossible without BIM.

688 Nanjing West Road, Shanghai

This 24-story Grade "A" office development (see Figure 7) included a number of floors dedicated for trading use, with a podium dedicated to retail and restaurant facilities, supported by three levels of basement.

Figure 5. BIM model vs. construction. Source: AECOM BIM Team

Figure 6. DZL, Shanghai. © G./V./P. Feng (Shanghai) Real Estate Development Ltd.


Figure 7. 688 West Nanjing Road, Shanghai. © Henderson Land Development

From the initial concept design, the developer considered the feasibility of incorporating sustainable solutions, and in doing so the vertical story height was set. The building utilized a composite structure, with a concrete core and structural steel frame. The structural steel frame allowed larger penetrations for the appropriate distribution of services, and the improved ability to use the ceiling void as a return air plenum as well as access for services into and out of the core. The layout grid was adopted to cater for the open plan office with single-occupancy, or multiple-occupancy format, with an internal escape corridor around the core. The building envelope was considered for enhanced performance and associated equipment selection and performance control.

BIM modeling, including architecture, structure and MEP, was adopted for partial areas, including all basement and lower podium floors, major plant rooms and typical floors. At completion, as-built drawings were entered into the BIM model for future use by the owner for building operations and management.

This building considered both user requirements and adaptability, adopted a process of design coordination across the design team through the adoption of BIM and applied standards that were measurable in terms of energy savings. This should allow for extended building life and good working conditions, all of which will contribute to the commercial success of the project.

This too, was only a success as a consequence of the use of BIM, which in this project and many others, was the catalyst for enhanced communications and improved design. Coordination of design and construction information occurred while energy consumption analysis was generated to ensure the building performance met targets (see Table 1).

Ultimately, the building achieved LEED NC Gold and Hong Kong BEAM certification on the basis of its HVAC, lighting, and daylight controls, domestic hot water, and renewable energy systems.

Remodel of existing floors at the Shanghai World Financial Center

Located at Levels 60 and 61 of the Shanghai World Financial Center, a two-level interior remodeling project required the engineering design to accommodate, in addition to pure office functions, services for a full restaurant kitchen, dining and lounge facilities, a gymnasium with full shower and locker room capability, server rooms, meeting/training rooms, and a games area, all compressed into 5,000 square meters (see Figure 8).

The new improvements were focused on indoor air quality, and achieved increased fresh-air rates 30% higher than ASHRAE90.1-2007, and enhanced filtration levels to the MERV13 (American Standard) or F7 (European Standard) for recirculated and fresh air. This was augmented by indoor CO_2 monitoring of the main meeting rooms and individual offices, and material selection with reduced VOC emissions. Additional energy savings were achieved through the use of LED lighting and enhanced control systems, which introduced 29.2% energy savings compared to ASHRAE90.1-2007. The use of Energy Star-rated equipment, a requirement of LEED, shows beneficial reduced energy consumption, according to post-occupancy evaluations.

Working within the constraints of the existing base-build MEP systems, these modifications were completed and approved by the client and the base building owner, and in the process created a new benchmark for future office developments that the client intends to build. The project embodies sustainable design solutions in terms of adaptability for the future, variable environmental conditions to suit various end-user activities, and a life-safety system built to FM standards, as well as to local code.

This project is an example of the importance of fully understanding the client's operational needs and designing accordingly, providing a user-friendly, adaptive and flexible working environment, essential to drive the effective and efficient performance of the users. The project achieved a LEED CI - Gold certificate.

Multi-story Research and Development Campus

This development in Shanghai encompassed four office buildings and two laboratory buildings, plus a cafeteria building. A combined basement accommodates a variety of facilities, including an animal center, energy center, car park, and plant rooms, including a bomb shelter.

"Green" technical solutions were incorporated, such as Variable Air Volume (VAV) ventilation, chilled ceilings, chilled beams, displacement ventilation/sub-floor air conditioning, fresh air

Category	Baseline 1 (Boiler system) consumption (kWh)	Baseline 2 (Heat pump system) consumption (kWh)	Design case consumption (kWh)
Lights	2,049,337	2,049,337	1,407,423
Equipment	2,088,138	2,088,138	2,088,138
Elevators	1,492,171	1,492,171	1,492,171
Heating	170,560 (Electricity) 10,604 therm* (Natural gas)	265,813	433,754
Cooling	1,402,791	1,402,650	1,012,125
Heat Reject	30,854	30,852	23,391
Pumps	991,740	990,318	636,459
HVAC Fans	827,881	828,016	924,480
HVAC Independent Fan	1,477,765	1,477,765	1,182,844
Exterior Lighting	255,132	255,132	255,132
Total	**11,097,067**	**10,880,192**	**9,455,917**
*1 therm is equivalent to 29.3 kWh Energy Reduction of Design Case compared with Baseline 1 =14.79% Energy Reduction of Design Case compared with Baseline 2 =13.09%			

Table 1. Energy consumption comparison for 688 West Nanjing Road, Shanghai

Figure 8. The remodelling of Level 60 and 61 of Shanghai World Financial Center, Shanghai. © AECOM

and exhaust air volume CO_2 control, rainwater treatment and recycling, and solar water heating. BIM modeling was carried out to demonstrate the design's maintainability and accessibility, fully modeled in five buildings. Design deliverables were required to meet high international standards including bilingual (Chinese and English) documentation and full code compliance.

The initial requirement for the design was to address the building envelope. If low energy consumption was to be achieved, a high-quality, high-performing envelope was essential both in terms of U-value thermal transmittance and air leakage. Shanghai has a very wide band of external environmental conditions with periods of both very low and very high humidity.

Applying radiant cooling installations requires control of both fresh air and the operating temperature of the ceilings and chilled beams. Natural smoke ventilation and stair pressurization were desirable strategies and simplified the design from a safety perspective in some buildings. A column-free environment with a full-height, triple-glazed façade required the application of CFD modeling to ensure the application of internal blinds was fully integrated with the perimeter air return system, glare and daylight calculations, and the application of lighting control to create an environmentally acceptable working space adjacent to the perimeter wall. To comply with environmental discharge requirements and dispersion of contaminated kitchen air exhaust plus fume cupboard exhaust sitewide, CFD site modeling was adopted to reduce any opportunity for re-entrainment of this contaminated air.

Conclusion

There is without doubt a requirement by local and international developers to address the question of sustainable design, and the parameters of this requirement are amplified when designing tall buildings that require enhanced coordination. Equally, there is an increasing requirement for designers to have a wider understanding of how such measures may be implemented into designs with surety of performance and cost-efficiency. A disciplined process of examination is required at the early stages of the design, with a better and more closely controlled concept design report. Key parameters that meet the cost objectives must be set down, and as services comprise ever-greater portions of operating cost and impact heavily on energy efficiency, building services engineers must play a greater role in supporting this part of the process. BIM should be implemented, not only as a design tool, but also as a catalyst to encourage stronger design cooperation amongst the various disciplines.

New technology to assist in the design process is essential. We will see an increasing use of 3D modeling, building performance models and life-cycle costing to ensure better outcomes. Considering the technical innovation that may be adopted in engineering design solutions with embedded sustainability, the following factors must be considered when designing for sustainable vertical urbanism:

- A greater focus on end-user requirements and methods of operation.
- Consideration of today's design requirements, and the wider implications of adaptability in the future.
- A greater need to consider construction techniques that allow spatial accommodation for engineering systems.
- While BIM does refine the design to improve space efficiency, it equally reduces the building tolerance that can be accepted in construction. ■

Author's Note:

The views expressed in this manuscript are those of the author and do not necessarily represent the views of AECOM.