THE SECRET OF ICONS

THE SPACE RACE

THE SECRET OF ICONS

THE SUPER SLENDER REVOLUTION

IS THE SKY THE LIMIT?
This has become even more the case over the last ten years, as buildings have become much taller and slimmer. A couple of decades ago, a building with a height-to-width ratio higher than 12:1 was unthinkable. Now buildings of 15:1 or even 18:1 are becoming reality.

We are always trying to push the envelope and tap into new technologies and materials. The buildings we’re designing now are made possible by the speed, depth and breadth of the engineering analysis we can do with today’s design tools. These allow us to produce economical designs in a much shorter time, as well as to study far more complicated building geometries than would have been possible a few decades ago.

There’s no theoretical limit on how tall a building can be. The limit is set by the ambition and by the available technologies, in materials, in construction and auxiliary damping systems, but also in elements such as elevators, so all the different sectors of the industry need to work together to make taller buildings a reality.

In established cities, where real estate is very limited, the available land may be an irregular shape. That adds yet another dimension to the challenge: how to create a viable design proposition that makes sense from all angles. Today’s tools and our in-depth understanding of how tall buildings behave allow us to engineer more complex projects to a more refined level, eliminating problems before construction and minimising the risks.

Engineering high-rise buildings is half art, half science – an artful application of science empowered by experience. It gives you an enjoyment that you may not have in other fields of endeavour – you can see the results. The beginning of a project is like a new puzzle to solve and at the end there is a sense of accomplishment. We hope this magazine offers a flavour of some of that excitement.
Why do we build tall buildings? On one level, it's simple logic. When there's high demand for space and very little available land, building vertically is the only answer. It's no accident that many of the world's tallest buildings are clustered on its most crowded islands, from Manhattan to Singapore and Hong Kong.

In the late 19th century, developers in the booming cities of Chicago and New York seized upon advances in engineering to create the first skyscrapers, as demand for land far outstripped supply. But high-rise construction quickly took on a momentum of its own. As engineers continued to make breakthroughs in building structures, wind and earthquake resistance, lift technology and construction methods, the race for the tallest building began – a race that has never stopped.

High-rise construction has become shorthand for ambition, success, prosperity, technical achievement. Today, a city’s skyline is one of its defining characteristics. Cities that built high have come to be recognised the world over simply by their silhouette, while others are seeking to create their own iconic skylines with a startling range of ever taller, more daring structures. Newer cities use towers to put themselves on the map, to announce they are open for business, as a very visible demonstration of all they have to offer. In established cities, meanwhile, high-rise buildings can be a tool for revitalising less prosperous districts, regenerating them by changing their image to draw in investors, tourists, new workers and residents.

More than half of the global population now live in cities, and by the end of the century, they will be home to another 3 billion people. For planners in the developing world, towers are an essential way to densify urban development and avoid the sprawl that characterises many western cities. Meanwhile, in the developed world, there’s an influx back into city centres from the suburbs, as people choose high-rise apartment living over an ever-longer commute. This is driving a boom in residential towers across Asia and in cities such as New York, Toronto, Vancouver, Melbourne and Sydney.

“The mantra of urban planning over the last 100 years was to separate where people lived from where people worked, but the next generation wants to live close to the city centre, whether for work or for access to services or entertainment, or a change of lifestyle,” says Paul Katz, managing principal at Kohn Pedersen Fox. “It will happen in different places in different ways, because it’s a cultural shift and that takes time. In Hong Kong or Singapore or New York, people are acclimatised to high-rise living. In other places, like Canada or Australia, it’s picking up. In London, it’s only just starting and will take time.”
There is increasingly this idea of creating mixed communities within a tall building. Combining residential with hotels and offices isn’t a new concept but people are starting to think about it differently. Hudson Yards is so vast that we’re trying to take a new approach.”

Richard Pilkington, Oxford Properties

Growing pressure on city centre land makes the commercial case for towers stronger than ever – and is also driving the development of ever thinner, “super-slender” towers (see page 14). The higher the building, the bigger the lettable area and the greater the value of the investment – an irresistible equation for developers.

Towers do cost more to build, but they also earn higher rents – an office with a view typically commands a premium of 20-25%, says Richard Pilkington, senior vice president and managing director at Oxford Properties, a global real estate business with joint venture interests in London’s Leadenhall Building (the “Cheesegrater”), New York’s Hudson Yards multi-tower development and 100 Adelaide W in Toronto.

High-rise premium office space is an essential component of a city’s offering to potential investors, he adds. “International tenants occupy high-rise buildings in New York, Hong Kong or Singapore, so they want to occupy them elsewhere too.” The Leadenhall Building, for example, is at the heart of London’s insurance district, and was attractive enough to lure Aon, one of the world’s largest brokers, to relocate its global HQ from Chicago.

Pilkington believes high-rise buildings offer another less tangible benefit as part of an investment portfolio. “People talk about trophy buildings,” he says. “It’s difficult to define, but we think that yields on towers are more sustainable in the long term. They’re potentially a better investment product, and may be less vulnerable when there’s a downturn. It’s almost as if people are prepared to pay a premium to own the building because it’s more iconic.”

There is an undeniable glamour about high-rise buildings that their mid- and low-rise counterparts can rarely hope to achieve. Creating an iconic tower has become a top priority for emerging world cities, as an unrivalled way of attracting attention on the global stage. Simply being tall, however, is not necessarily enough. Wuhan, the capital of central China, has just unveiled plans to build the world’s tallest tower, part of a pair that will filter its polluted air and lakes. “It’s blatantly iconic, but it also does a job,” explains Laurie Chetwood, founder of Chetwoods, architect of the Phoenix Towers project. “They wanted to take the Eiffel Tower experience a stage further. This doesn’t just stand there as a symbol of Wuhan, it will also showcase its social, economic and environmental sustainability and become the nucleus of a wider green strategy for the region.”

In established cities too, an iconic building can exert a powerful economic effect, says Agneta Persson, global director, designing future cities.
at WSP. “High-rise can be a catalyst for regeneration. A high-profile building can attract new investment to an area and really turn it around. Businesses relocating to the area bring in jobs, and that in turn leads to the opening of new shops and other services.”

This has been amply demonstrated by the Shard, the centrepiece of a wider development known as London Bridge Quarter, which is already putting up strong competition to the City, the West End and Canary Wharf for commercial tenants and tourists alike. In addition to the building itself, Sellar Property Group spent over £62m on improvements to the public realm and the station and bus station next door. It also built a 27-storey office building, to be the new UK headquarters for News Corporation, and now plans a 27-storey residential tower next to the Shard. And there will be more to follow: “This is the nucleus of a new district for London that will expand,” promises Irvine Sellar.

Like many capital cities, London exists because it provides the commercial, cultural and intellectual attractions that people want, and through this it has become a perpetual engine of rediscovery, reinvention, reinvigoration and legacy. To survive and be successful, it needs to evolve, develop and expand. However, this naturally promotes population growth. So how do we react? Do we expand vertically, or laterally into suburbia, exurbia and the greenbelt?

That’s a very pertinent question for many cities at the moment. London’s response has partly resulted in the transformation of its skyline. More than 200 buildings over 20 storeys are planned, which is causing quite a stir. I would support the idea of a “skyline commission” for a more structured, defined and considered policy that would merge existing policy documents, mimicking New York’s prescriptive zoning, Singapore’s “Gardens in the Sky” and Vancouver’s enhanced planning procedures which improve designs through peer review.

I believe that densification is preferable to urban sprawl, and that tall buildings offer a solution to various issues that urban growth raises. But building vertically is not the sole answer. It is essential to consider the relationship between height, urban density, urban circulation and infrastructure. Physical mobility and accessibility affect economic mobility and are key to delivering a sustainable city.

The siting of tall structures needs to be reviewed holistically. Densification can be provided with the siting of carefully planned clusters of towers, located on or close to key transportation hubs alongside low-rise development and open space to boost regeneration. Any increase in density leads us to reconsider how we provide public and amenity space.

London is not as advanced as Malaysia, say, where developers have to achieve a provision of open space equivalent to the original site. This forces intelligent thinking about private/public sharing of space within buildings, something London needs to emulate.

When designing a tall building or skyscraper, there is a tendency to focus on the building itself, but architects must also consider wider contextual issues. These include city-wide view corridors, impacts on lower-rise buildings and on the ground plane, as well as microclimate issues such as altering city wind patterns, creating shadows or glare and affecting building and surface temperatures.

Do we need tall buildings? Yes, but as part of an integrated whole. They should respond contextually within the city rather than solely to local clusters, represent design excellence and be a catalyst for lower-level regeneration.
Part of the glamour of high-rise comes from the technical and commercial feat that building a tower entails. By its nature, an iconic building is something new, different and very ambitious – which inevitably presents considerable risk. “It’s a big, big leap of faith,” says Pilkington, particularly for speculative developments. “Once you start building, you have to finish – you can’t phase it, so that gives you less flexibility. Tower construction programmes are difficult to predict. A key example is that the higher up the building you go, the more vulnerable to the wind you are. That’s combined with the risk of letting to tenants – we give them a commitment that the building will be finished on a certain date, but the taller the building, the more unpredictable the completion date. You’ve got to have an appetite for that sort of risk profile. Everything is more constrained, the risks are higher, so you’ve got to be comfortable with that type of product and the journey you’re going to go on.”

One way to manage the commercial risk is to include a range of building uses, which also meets demand for more varied city centres. Current thinking on high-rise buildings envisages them as communities rather than monolithic entities – whereas the earliest skyscrapers were purely commercial, today’s super-tall buildings combine residential, commercial, hospitality, leisure, and even green spaces.

In the future, occupants of towers may never need to leave at all, if they don’t want to. For example, the redevelopment of the Hudson Yards site on the far west side of Manhattan will create a complete city quarter spread across 16 skyscrapers, with offices, shops, homes, bars, restaurants and cultural spaces, interspersed with outdoor parks. Each residential tower will combine apartments and amenity space.

As cities continue to grow and develop, lifestyles of future urban dwellers could be very different from what we know today. “High-rise buildings are an essential component of the continued sensible and sustainable growth of cities for a whole load of reasons,” says David Cooper, chief executive of WSP USA. “Now we see long commutes driven by urban sprawl, but perhaps in the future, we might start talking about vertical commutes instead.”

“Agha Hasan, WSP Canada

“Sustainability is an essential facet of design in many jurisdictions. Tall buildings offer high-density working and living conditions, and that makes them energy-intensive, but the dream of zero-energy towers is not too far from realisation.”
AS TOWERS GROW EVER HIGHER AND SLIMMER, WE CONSTANTLY NEED NEW WAYS TO DESCRIBE THEM ... 

Tall is a subjective concept, and attempts at an absolute definition seem destined to be foiled by engineering ingenuity. A skyscraper is defined as a tall, continuously habitable building, but there’s no official minimum height. Originally the term didn’t even apply to buildings – it was used variously for the sail on a boat, a very tall hat or even a high-standing horse, before a journalist in 1880s Chicago seized on it to describe the boom in high-rise steel-framed construction.

Chicago’s 10-storey Home Insurance Building is considered to be the world’s first skyscraper, completed in 1885 and 42m (138ft) tall. Since then, it appears that the sky has got further away. Today, a height of 50m (165ft), or around 14 storeys, is sometimes considered the threshold for a “tall” building, although 150m or 30 storeys is also used. The Council for Tall Buildings and Urban Habitats defines “supertall” as over 300m (984ft). There are currently 78 supertall buildings around the world, and just two “megatall” towers of more than 600m (1,968ft). But with the 1,000m-plus Kingdom Tower currently under construction in Saudi Arabia, we may need a new category before too long.

Whether a building is tall or not also depends on where you are, says Richard Pilkington, senior vice president and managing director at Oxford Properties. “London is not a very high-rise city, so you start to get a pretty good view at about level 12 in the City. But that would be very different in New York where buildings can be 100 storeys.”

In fact, New York’s most advanced towers are defined not by their height but by their width – or rather, their slenderness. This is the ratio between a building’s height and its smallest width: so a 1,000ft tower that is 100ft at its narrowest point would have a slenderness ratio of 10:1. “The slenderness of a building is maybe more important than anything else,” explains Silvian Marcus, director of building structures at WSP USA. “Slenderness is crucial to the behaviour of a building, but a building doesn’t necessarily have to be tall to be slender.” In New York’s building code, designs for buildings over 600ft (183m) must be peer reviewed by another engineering practice, but so must any building with a slenderness ratio above 7:1. A 500ft tower with a width of 50ft would still have a ratio of 10:1, Marcus points out.

The twin towers of the World Trade Center were considered to be very slender, with a ratio of 9:1. But WSP’s latest New York projects are far skinner. Construction is nearly three-quarters complete on “super-skinny” 432 Park Avenue, which will be the tallest residential tower in the western hemisphere. At 1,397ft high and 95ft 6in wide (420m by 29m), it will have a slenderness ratio of 14:1. But that’s nothing compared to 111 West 57th Street, due to complete in 2016. Standing 1,425ft (434m) and just 59ft (18m) wide, its height will be 24 times its thinnest point. Does that make it “mega-skinny”? *}
A Q&A WITH IRVINE SELLS, THE MAN BEHIND THE SHARD—LONDON’S FIRST SUPERTALL TOWER
Q — Why did you decide to build a new high-rise building in London?

A — We originally bought a building called Southwark Towers in May 1998, which stood where the Shard stands now. It was bought as an investment property. It had a long lease, with 90 years left, 14-year rent reviews, good yield and was a good safe investment, which I was quite happy with.

But perhaps a year after we acquired it, a government white paper emerged which said they would encourage high-density development providing properties were close to transport hubs. Our building sat right next to, and partly on top of, London Bridge station. That’s when the idea came. Although Southwark Towers was a 24-storey building of 200,000ft², I saw the opportunity to maximise that to well over 1 million ft². Any property we buy, we look for angles. So it fell into that category, only bigger. Even though the Shard isn’t a straight-up-and-down tower, we’ve still got 30 acres of space on a one-acre site. That’s got to be a world record.

Q — Where did the “vertical city” idea come from?

A — That was the concept right from the start. It was commercially based. I wanted a tower that was balanced in terms of its uses, because in property, if retail or commercial goes down a bit, it doesn’t necessarily affect residential. If residential falls, it doesn’t necessarily affect offices. So I thought, if we’re going to build big, we should have a mix of many uses.

Q — How quickly did the “shard” design come about?

A — We’d developed some CGIs of a tower over 400m with a local architect and we put out a press release. That got an amazing reaction, which gave us encouragement. Then we went back to our drawing board and one of our team said, ‘If we really want to stand a chance of getting planning consent, we’ve got to use an architect that’s international, that’s at the top of their game.’ He knew Renzo Piano, who was exhibiting in Berlin, so we met there in May 2000 and had lunch.

I showed him our CGIs and he said, ‘You know, I don’t like tall buildings Irvine.’ He said he found them aggressive symbols of arrogance, fortresses, impenetrable etc. I thought, this may not be the best meeting I’ve ever had… Then he stopped suddenly. He said, ‘But I see the beauty of the river, the energy of the rail lines, I see it like a giant sail or an iceberg.’ And as he was talking he flipped over the menu and started drawing. That sketch is famous now, because what he did in 30 seconds bore a very strong resemblance to the Shard you see today.

“ In London, we haven’t had our Eiffel Tower or our Empire State. But now we’ve got the Shard, and I am privileged, with my team, to have delivered it.”

Q — You’ve said that you got the Shard built by being “unreasonable” – what did you mean?

A — We had all the odds working against us and there was complete disbelief that this was going to happen. But there weren’t many options – we had to win. My role has been to sell the idea to everybody, motivating and convincing myself and everybody else that this is going to work, this is going to be special. We had a great team, but a team always need inspiration. I’m driven and I think if you’re driven as a leader, you drive the team. With a fair amount of aggressive charm – aggression probably more than charm – we worked our way through it.

Q — Did you ever think it wouldn’t happen?

A — There are nights when you don’t sleep so well, but you must never show doubt. As soon as you show vulnerability it will affect the team. In early 2012, when we were nearly complete, Renzo and I were on-site at level 87. He turned to me and he said ‘you know Irvine, if we weren’t both a little bit mad, this would never have happened.’ And I think he had a point.”

Credit: Nicola Evans, WSP Group
What makes a building “iconic”? It’s a term that’s often used by developers and urban planners, seeking to create a building that will be memorable, successful, popular, and perhaps even come to symbolise its location or its owner. But how do building designers go about creating a new landmark for a city? Being tall is certainly an advantage when it comes to attracting attention – high-rise buildings literally stand out from the crowd – but it’s far from the only attribute of a genuine icon.

By definition, icon status is something only a minority of buildings will, or should attempt to, achieve. "Not all of the buildings in a city can be iconic," says Paul Katz, managing principal at Kohn Pedersen Fox. "You could argue that a successful city is one where there are very few icons. If you think of very successful urban precedents like Paris, you’d be hard-pressed to name a specific building that’s an icon, apart from the Eiffel Tower. What you remember is the space of the streets, squares and gardens."

Katz believes that the majority should be "background buildings", designed primarily to perform their function well and provide amenities for the people of the city. "The real purpose is to build a building of quality that fits a certain purpose. A building of quality is not necessarily an icon, and an icon is not necessarily a building of quality. It’s more difficult to design a commercial building that’s an icon."

The Eiffel Tower serves very little practical purpose, he points out, and that’s part of its appeal. As for what does make an icon, it often comes down to the estate agent’s mantra: location, location, location. "Architecture is like any art form – you try to create something that really matters," says Joost Moolhuizen, partner at Renzo Piano Building Workshop. "The most exciting projects have a wider significance for the public realm. What we’ve learned over the years is how important it is to understand the locality. We don’t just start a project with the meetings and brief. We go to the site, try to take it in, soak up the atmosphere."

Moolhuizen was lead architect on such well-known landmarks as the Shard in London, the KPN Tower in Rotterdam and several of the buildings on Berlin’s Potsdamer Platz, but he believes that great architecture begins as a response to its context, rather than setting out to be loved. "You don’t start by saying you want to design a popular building. Architecture tries to tell a story – it may be a good story or a very boring story. An iconic building expresses something, and it captures people’s imaginations whether they like it or not."

Katz agrees: "An icon usually leverages specific characteristics of its context, either by juxtaposition or by reinforcing something. For example, the tallest building in the city usually catches the light in a really beautiful way, and it becomes very sculptural and elegant through verticality and expression. There’s a spiritual aspect of connecting the sky back to the earth."

The design of a tall building relies on much more than an architect’s vision. "The development of high-rise buildings is as much infrastructure as it is architecture, and it’s the dialogue and the relationship between the architect and the engineers that is really crucial," says Katz. "It’s almost impossible to teach tall buildings at university, so you really learn by doing it in the real world where the knowledge is handed down. The history of high-rise architecture is therefore a personal story of individuals contributing to a common endeavour."
SKYSCRAPERS VS GROUNDSCRAPERS: WHICH IS MORE SUSTAINABLE?

Can a skyscraper ever be greener than a low-rise building? Viewed in isolation, the simple answer is no. “With today’s technology, a tower will always be more energy-hungry,” says Philippe Honnorat, head of building services at WSP UK. “If you’re going to wash or take a shower on the 80th floor, you have to bring the water up there. When you take your shopping up to your apartment in an elevator, that will consume more energy than if you lived on the ground floor. Towers also require greater mechanical cooling to remain at a comfortable temperature: “A high-rise building standing out on the skyline effectively becomes a sun capitalisation device, and you can’t just open a window on the 80th storey because there is so much wind.”

But zoom out to city level and it’s a different story. The United Nations predicts that the world’s urban population will rise from 3.6 billion to 6.3 billion between now and 2050. To accommodate these new residents, the cities of the future will have to be much denser – and that means building higher, says David Cooper, chief executive of WSP USA. “High-rise buildings enable many people to live, work, spend their leisure time or access public services in a relatively small area and that drives more efficient mass transportation. From an urban planning point of view, towers are very sustainable.”

High-rise developments that combine offices, homes and other uses enable more efficient use of resources, he adds. “Residential buildings typically have different usage patterns to offices, which presents opportunities to share energy and equipment. Technologies such as cogeneration become much more efficient when, for example, waste heat from office cooling can be used for hot water for apartments. We need to start creating vertical communities instead of sprawling horizontal ones.”

Low-density development also consumes greater energy in less obvious ways. Compare New York and Los Angeles, says Honnorat. “In Manhattan, most people don’t even own cars, whereas LA has lots of low-rise, low-energy buildings that can only be reached by car, and require extensive energy and water infrastructure. On a building-by-building basis, it’s a no-brainer that towers use more energy, but when you look at the bigger sustainability agenda it’s far less clear.”

Energy is just one aspect of sustainability, and one which will become less significant as technology improves. Honnorat argues that land is a much scarcer resource and one that is genuinely finite, subject to a range of competing demands from a growing population that needs housing, food and access to green space. Meanwhile, humans are surrounded by free solar, wind and tidal power – if only we could harness enough of it. “Consider a future where instead of being 5% or 10% efficient, photovoltaic cells are 30% efficient,” he says. “All of a sudden, the solar-capturing ability of a high-rise building comes into its own. If we manage to make that quantum leap in technology, it’s a very different equation.”
It’s the engineer’s role to bridge the gap between aspiration and reality, says Henry Huang, director at WSP in Shanghai. He is working on supertall towers in Dalian and Shenzhen, the ambitious cantilevered designs of which must also be strong enough to withstand frequent tornadoes and earthquakes. “Clients always have high expectations, so we try to realise their dreams while making the costs more reasonable. We have to make sure a building is actually constructible, not just a paper dream. We’re always working closely with the whole design team to try to solve problems quickly and move the project along.”

So how do the engineering challenges of a high-rise building influence its appearance? Ideally, as little as possible, says Philippe Honnorat, head of building services at WSP UK – if enough attention is paid to the detail. “High-rise buildings have a much bigger impact on our visual environment, so they have to be designed better. One of the things that we should be very proud of at the Petronas Towers in Kuala Lumpur is that you don’t see any grills or technical floors, it just looks like a perfect, effortless shape rising into the sky. That’s because the architecture and the engineering were integrated very closely.”

Structural engineers work not only to realise the architect’s vision, but to make it economical to build. WSP’s Melbourne-based team has built up a strong track record in optimising structures so that they are more cost-effective, which makes them much sought-after among high-rise developers. “The cost of the structure accounts for a higher proportion of a tall building’s total cost, so there’s a great opportunity for structural engineers to add value,” explains director Mark Hennessy. “On a tall building, the difference in value between a good design and a less good design is quite significant – it could be 20-25% of the total structural cost.”

Advances in the strength of steel and concrete, in auxiliary damping devices for better controlling a building’s movement and in computer modelling are making it possible to create structures that would have been unthinkable even a decade ago, from the rippled facade of Frank Gehry’s 8 Spruce Street to the pencil-thin luxury residential towers taking shape at 432 Park Avenue in New York’s Midtown. “We are always trying to tap new sources of technology and materials to make taller buildings and challenging designs possible,” says Dr Ahmad Rahimian, director of building structures at WSP USA. “In New York, we have been able to successfully implement very high strength concrete, up to 14,000 psi. Ten years ago, that wasn’t possible. The buildings we’re designing now are also made possible by the level of engineering analysis we can do today, which allows us to produce a more economical, responsive and refined design. We can essentially construct the building in virtual reality to resolve conceptual issues and ensure that it proceeds more smoothly on site.”

Outside of seismic zones, the most significant force that a high-rise building must contend with is the wind. “The taller the building becomes, the greater the effect of the wind – just as if you had a sailboat with a bigger sail and a bigger mast,” explains Rahimian. The engineer’s aim is not to prevent the building moving at all, but to reduce the movement and its acceleration to a level where most people will be unaware that it is happening. “It’s not a linear process as you go taller and taller. When you reach a certain height, above 400m or 500m, the wind flow is more like what an aeroplane would experience. The wind pressure acting on the building has an almost direct relationship to the height, but the overturning forces that will cause it to tip over increase exponentially to the power of two. And the building motion that we would feel would rise to the power of three. So the challenge of creating a building that will be comfortable for the occupants increases exponentially.”

Since 9/11, engineers have also been deploying high-strength materials and high-power computing to make tall buildings more robust in the event of an extreme event. “We don’t do that by creating a fortress, but by analysing the ultimate behaviour of the building under an extreme event and reinforcing it with the optimum amount of material,” says Kamran Moazami, director and head of structures at WSP UK. With advances in high-power computing, engineers can now carry out hundreds of model runs to determine exactly how a building will behave in the event of an attack and systematically refine the design. “Two decades ago, it was extremely difficult, expensive and time-consuming to carry out this level of analysis for a single building.”

“With the early skyscrapers, many assumptions were made that were a little more conservative because there was a lack of knowledge,” agrees Silvian Marcus, director of structures at WSP USA. “Now we can replicate the actual construction, subject to parameters that buildings are subject to in real life, like wind, seismic movement, changes in temperature, even icing formation and whistling in high wind.” This provides the whole design team with much greater certainty of how a design will perform in reality – the key to creating a genuine building of quality.

“One of the things that we should be very proud of at the Petronas Towers in Kuala Lumpur is that you don’t sense anything technical about it – you don’t see any grills or technical floors, it just looks like a perfect, effortless shape rising into the sky.”
New York is once again leading a revolution in high-rise design, but its newest skyscrapers are distinguished not only by their height but by their extraordinary slenderness. In the last five years, a crop of pencil-thin towers has begun to spring up on tiny plots, many clustered around the edges of Central Park in Manhattan’s Midtown.

New York’s building codes consider a building to be slender when its height is more than seven times its width. But WSP is now delivering buildings that double and even triple this. One of the first examples of the trend is the just-completed One57, designed by French architect Christian de Portzamparc. It has become the tallest residential building in the city at 306m, with a slenderness ratio of 8:1. But it will very shortly be overtaken by 420m-high 432 Park Avenue, where construction is around three-quarters complete, and which boasts a ratio of 14:1. This will be followed by 56 Leonard Street, due to complete in 2016, MoMA Tower, 15 Hudson Yards, and the needle-like 111 West 57th Street, which has a mindboggling height-to-width ratio of 24:1.

Unlike the majority of New York’s towers, these buildings are not commercial offices but luxury residential developments. “The key difference is that the floorplates are not as big as conventional offices, and because these are luxury apartments, developers want the bulk of them to be physically located above neighbouring buildings, so that they have a view,” explains Jeff Smilow, director of building structures at WSP USA. “That’s given rise to these very slender ratios.”

The key challenge for engineers is to manage the building’s response to the wind, and specifically its acceleration – in a car, you only sense the movement when accelerating or braking, not when travelling at a constant speed. “A person coming home to the 50th floor in a building does not expect to move in the wind,” says Silvian Marcus, director of building structures at WSP USA. “It’s impossible to stop the building from moving, but you can control the movement so that the majority of people will not feel it.”

Residential buildings have to perform much better than commercial buildings, adds Smilow. “With a commercial building, you can evacuate if there’s a hurricane, but in a residential building people live in it and they have to feel safe in it regardless of the weather. The criteria are much more stringent.”

But engineers must do this without many of the traditional tools at their disposal. An office tower’s concrete core is a traditional source of stiffness, but this too is much smaller in a residential building. Maximising usable space is even more important in such slender towers, and unobstructed views are a key selling point. This means that simply beefing up the structure is not an option either.

“One option is to adjust the shape of the building to make it more aerodynamic, introducing openings to allow the wind to pass through or adding curves at critical locations along the facade to minimise the “vortex shedding” response which causes high acceleration. WSP works closely with architects to refine the shape of the building, using wind tunnel analysis. There are also a range of structural systems that can improve the building’s stiffness without obstructing the layout, as can the use of high-strength concrete. “The goal is to find out what works, what shape responds best to the wind and reduces the acceleration, not just to add structure unnecessarily.”

Such tall buildings will also require a damper to slow the movement, but even here the structural engineers seek to minimise material. “We always feel we’ve reached our goal when we can eliminate the damper. We can’t do that in very tall buildings, but we can use a less expensive type of damper.”

“A person coming home to the 50th floor does not expect to move in the wind. It’s impossible to stop the building from moving, but you can control the movement so that the majority of people will not feel it”

— Silvian Marcus, WSP USA
MEET THE VERY SELECT GROUP OF SPECIALISTS CREATING THE WORLD’S SUPERTALL TOWERS
High-rise buildings are instantly impressive achievements, the gargantuan effort of constructing them apparent to the most casual observer. But many of their most pioneering features are destined to remain hidden from view – technologies and techniques that come into their own behind the hoardings of the building site, or deep within the core of the building. It was the invention of the safety elevator that made the earliest skyscrapers viable – until that point, the most valuable properties were on the lower floors of a building. Since then, many breakthroughs in various specialist fields have continued to make ever taller, more efficient and more comfortable towers possible, from the high-performance glass of their facades to the sophisticated elevator systems that enable today’s vertical cities to function.

“People sometimes say that high-rise buildings are all about ego and power,” says Philippe Honnorat, head of building services at WSP UK. “But it’s also about challenge – surmounting the challenge and developing technologies that are eventually going to filter down to the entire industry. The high-rise is the R&D lab of construction.”

To date, a comparatively tiny number of supertall towers have been built – according to the Council for Tall Buildings and Urban Habitats, there are currently just 78 buildings over 300m, though there are at least 100 under construction and many more on the drawing board. Each of these buildings is a major construction event: completely unique, and often unprecedented in its local market, if not the world. This means that the teams responsible must draw on the latest, best solutions from a very specialised niche within the global construction industry. Skyscrapers are not only made possible by advances in engineering, they have also driven significant innovations in construction itself and contributed to their dissemination.

CONSTRUCTION MANAGEMENT:

The ever rising site

Show a construction manager a drawing of a skyscraper and they immediately see a series of risks that must be relentlessly, minutely and faultlessly managed. Mark Reynolds, chief executive of Mace, breaks it down into five key components: the groundworks, the frame, the cladding, the mechanical and electrical systems, and the lifts. “Those are the big five – the first questions that you ask.” Mace was contractor on the Shard in London and is now building the 1,000m-high Kingdom Tower in Saudi Arabia. And the secret to managing those risks? A rigorous command of logistics. At its heart, constructing a tower means transporting hundreds or thousands of workers to and from a site that is continually rising higher into the air, and which must be fed with a constant supply of materials.

“Logistics is the key to making tall buildings work,” says Reynolds. “Constructing a tower is all about volume, about the speed at which you can construct each floor. You have to maintain momentum, get the sequence and flow going efficiently and predictably.”

The Shard got off to a racing start using a method called ‘top-down construction’, where its three basement levels were excavated as construction of the above-ground levels began, saving around four months on the programme. Reynolds says that Mace now uses top-down construction on many of its projects, large and small.

With repetitive volume construction, precision is vital. One of the most significant breakthroughs of the last decade has been the use of GPS satellite technology to guide machinery on site, says Reynolds. The Shard’s concrete core, running from basement level 3 to level 72, was constructed continuously using a slipform equipped with GPS to keep it on course as it grew 3m per day.

This was key to the speed of construction, and provided stability as the building took shape. But it was also essential that the building’s crane grew at the same speed, or construction would grind to a halt. To ensure that it would always keep up, the crane was installed on top of the slipform – a world first. “The idea came from a project in the Far East, but it hadn’t actually worked there. So this is the first time it has been achieved successfully.”

The rapid growth of the core also enabled one of the most significant logistical breakthroughs on the Shard: the UK’s first use of jumplift technology, a vertical transportation method pioneered in the Far East and Australia. As the core rose, the six permanent lift shafts and a temporary motor room were built within it. This meant that the super-fast lifts that would serve the finished building could be used during construction, averting need to install temporary hoists. As each floor was constructed around the core, the lift capacity was already there to serve it. “That made a really big difference for access, the safety of the workforce and the quality of the working environment,” says Reynolds. He compares the Shard’s 38-month programme with the nine years it took to build London’s NatWest Tower, completed in 1980, where external hoists meant each worker lost up to four hours each day just travelling up and down.

“Logistics is the key to making tall buildings work. Constructing a tower is all about volume, about the speed at which you can construct each floor. You have to maintain momentum, get the sequence and flow going efficiently and predictably.”
High-rise buildings are typically built on tight urban sites, so all of this must be orchestrated within a very narrow area. At the perimeter, workers, tools and building materials – even individual nails – have to be firmly attached to the structure at all times. And then there’s the wind: “Above 17 floors, you start getting a big surcharge in wind and it increases exponentially. You can’t use the crane above a certain wind speed – above level 60, we were prepared for significant downtime. In the end, the crane could only operate for 40% of the time.”

To get round this, Mace drew from its own experience of constructing Heathrow’s Terminal 5, where offsite prefabrication was used to save time and avoid errors in the middle of a working airport. At the Shard, as much of the building as possible was assembled off site, reducing the number of journeys up and down the building for both workers and individual components, as well as the risk of error 300m in the air. Preassembling M&E components meant that only 90 workers were needed on site in place of 340, while the Shard’s 60m spire was designed as a series of modules with as few connections as possible, with a dry run in the Yorkshire countryside.

Among the team of specialists delivering a tower are two other vital functions: security and communications. High-rise inevitably means high-profile, and towers garner plenty of attention, not all welcome. The Shard attracted huge media interest after “Romeo” the fox was discovered living at the top of the incomplete building – toy foxes are now on sale in the gift shop. Meanwhile, the craze for base jumping from tall buildings is one of many reasons why effective round-the-clock security is essential. Base jumpers have targeted many tall buildings under construction, including the Shard and One World Trade Center in New York, although WSP also built the platform for a sanctioned jump from Dubai’s Burj Khalifa. “These are not projects you can get on with quietly,” says Reynolds. “If anything goes wrong, you’re in the papers.” Better make that one more risk to add to the construction manager’s list …
SUSTAINABILITY: Forces of nature

Hundreds of metres above the ground, the world is a very different place. A skyscraper exists in a different climate to a low-rise building, buffeted by high winds and fully exposed to the sun throughout the day. Maintaining a comfortable temperature and constant flow of fresh air is considerably more difficult up here, which has meant that high-rise buildings are typically high consumers of energy.

What’s more, many of the sustainability strategies developed for low-rise buildings do not work for towers, because of their shape and size, and the sheer density of occupation.

“It’s tricky because you have a very small area of land to work with, but a lot of people and a lot going on in that small area,” explains Susie See, executive vice president of WSP in San Francisco.

For any building, sustainable design always starts with a passive approach – improving the fabric of the building to reduce demand for energy, and making the best use of natural light and ventilation. By far the greatest element of a high-rise building is its facade, and it’s here that WSP’s sustainability experts begin.

The first step is to reflect as much of the sun’s energy as possible, the second is to open it up to natural ventilation. High winds are both a challenge and an opportunity, says Philippe Honnorat, head of building services for WSP in the UK. “In a sealed building, you have to constantly pump in fresh air and exhaust stale air – you don’t have to do that if you can open the windows, so you save energy. But opening the window at the 80th storey is not an easy thing to do, so we have to design the facade to achieve the same effect. This might be a kind of vent that you can pull towards you, so you get the fresh air but the wind doesn’t blow it off or blow a gale through your office. We are aiming for a mixed-mode approach, so you have the ability to shut down the air-conditioning when outdoor conditions allow, as opposed to being condemned to use it all the time.”

A tower’s relatively tiny roof area in relation to its size can also rule out conventional technologies for generating renewable energy, such as photovoltaic or solar thermal panels. So again engineers focus on the facade. See is exploring the use of building integrated photovoltaics (BIPV) within glass cladding, still in the very early stages of development. “It’s conceptually a very interesting solution, but it’s not there yet. BIPV generates very little electricity but the costs are very high, so it’s very difficult to get it to pay for itself.” She believes that it will take at least a decade before the technology is viable.

Neither is rainwater harvesting a viable option. “To capture rainwater, you would have to have it falling on a much larger area, so we have to look at how to reuse what’s been taken from the city system,” explains See. “The building has to pull in resources from outside, but we can reuse these over and over again.” Reuse of “grey” water from wash basins or showers is already well established, but it is increasingly possible to reuse “black” water from toilets – after an extensive treatment process, it can be used again to flush toilets or to replace water that has evaporated from cooling towers.

High-rise buildings also present opportunities that their low-rise neighbours don’t, particularly when they combine different types of occupier. Cogeneration or tri-generation systems burn gas to make electricity, and harness the waste heat to produce hot water, or to feed an absorption chiller, to produce cool air. In a purely commercial building, demand for hot water is comparatively low. But in a mixed-used tower, these systems could come into their own to feed apartments or hotel facilities. “These systems are most efficient when you can use all of the waste heat,” explains See. “The more we start thinking about high-density urban environments, the more we can share energy uses and achieve a greater energy balance within buildings. There is an inherent degree of sustainability in the ability to share resources and trade resources. It is a challenge but we’re starting to break down some of the strategies to get there.”

“The Salesforce Tower will be the tallest building in San Francisco, and is pre-certified LEED Platinum. It’s a showcase office development, right next to a large urban park on the fifth level of the new Transbay transit centre, and residential towers will be built around it. San Francisco is being transformed into a more vertical, denser urban environment, with a development that combines transit next to offices next to residential, next to great outside space. I think it’s going to be very successful.”

Susie See, WSP USA
WIND MODELLING:

Whipping up a storm

Want to know what the wind feels like 300m above the ground? Just go and stand next to a supertall tower. High-rise buildings are designed to withstand the fierce winds that swirl around their upper reaches, but unfortunately they also channel them down the length of their facades to the ground, disrupting life below.

Skyscrapers exert a well-documented influence on their local microclimate, from blocking out the sun to creating wind tunnels and pockets where temperatures are noticeably cooler. But these effects can be mitigated, and that’s what WSP’s microclimate specialists help clients to do.

Associate director Camilo Diaz heads up a specialist team that produces wind studies to support planning applications for new buildings. “Wind modelling plays an important role because we can identify any potential issues early on in the design process,” he explains. “So we can inform the design and say, ‘Don’t place the main entrance here because that’s the windiest corner’. Or if the design is fixed, we can use the model to identify the windiest areas and get a landscape architect involved to mitigate the effects by planting trees or including features like wind baffles or screens.”

The same tools can also be used to optimise the wind – WSP worked with architect Foster + Partners on Masdar City in Abu Dhabi to support its natural ventilation strategy.

Unlike the path of the sun, the dynamics of the wind are particularly complex to predict, but the technology to do so is evolving rapidly. Diaz’s team combines 3D computation fluid dynamics modelling to predict the air flows around a building with long-term historical wind data, then carries out statistical analysis to determine whether future conditions will exceed accepted thresholds. “A person standing about to enter a building can tolerate a certain wind speed and frequency, which will be different to a person walking, or walking fast – or at the other end of the scale, sitting with a coffee reading the paper. Then we can say, ‘This area is windy and could put pedestrians at risk’, or ‘Don’t designate this area for seating, put it somewhere less windy’.”

But crunching all this data consumes a vast and growing amount of computing power. “As buildings become taller, models have become larger and larger – it can take anything from one day to two weeks to run the model. For an accurate picture, we need a radius around the building of ten to 15 times its height, so for tall buildings we end up with a very big flow domain.”

The other factor increasing the size of the models is the methodology itself, which the team is continuously refining. WSP is about to begin an in-house research project to compare the results of traditional wind tunnel testing and computer modelling. “This is a very exciting area for consultants and scientists,” says Diaz. “We keep adding layers and layers of quality and innovation to our work, so for us, it is always an evolving process.”
In a human body, the skin is the heaviest organ and one of the hardest working, regulating our temperature and protecting the delicate operations within. It’s no different for a skyscraper. The facade is by far the most significant component of a tower, fulfilling all the obvious functions and quite a few others too.

As the primary barrier between the occupants and the elements, the facade system must be strong, fire, water and windproof and energy-efficient to support a LEED, BREEAM or Green Star rating – all on top of looking good. “A lot of people think of the facade as just the envelope of the building but it requires multidisciplinary skills and is linked to many other elements,” says Lucia Lung, a facade specialist in WSP’s Shanghai office. “It is a very complicated area.”

Designing a facade system encompasses structural engineering, building physics, materials science, weatherproofing technology, architectural detailing, production engineering, construction management and buildability. The facade also accounts for a significant proportion of project costs, so the engineer’s role is to balance visual and performance requirements to create an economically viable solution that can be built safely.

High-rise facades are becoming even more complicated as architects abandon the glass box in favour of ambitious multifaceted forms. Among Lung’s current projects are the Dongguan World Trade Centre, where the central tower measures 430m. “Within this single building, there are multi-sloped facades, a cantilever, chamfered corners, a lantern roof and a curved canopy. We have to work together with the architect and many other parties in the design team to develop the right solution and solve all the interfacing problems. That’s the most exciting thing about it for me.”
Every engineer secretly believes their part of a tower is the most important. But vertical transportation specialists have a better case than most. “Without elevators, or some other way for people to get up and down, there would not be tall buildings,” says Steven Truss, WSP’s VT technical director. “You wouldn’t build a 100-floor tower and walk up the stairs, would you?”

A VT strategy can make or break a development. “Elevators take up a huge amount of space and that means less revenue for the developer. If you have a very tall building with a small footprint and you design in too many elevators, the project may cease to be viable. It’s always a balancing act. Too many elevators is a waste of capital cost, running cost and space, but too few and the building will never quite function properly.”

Capacity is a complex calculation, with many variables. Occupancy levels vary significantly between, say, trading floors and the executive suite, and between high-end apartments and social housing. Designers typically assume 80% capacity for lift cabins, but this drops to 60% in hotels, where people will have luggage and, intriguingly, in external glass elevators, to give vertigo sufferers more space: “Not everybody wants to stand at the back looking out,” points out Truss. Acceptable waiting times range from 25 seconds in offices, to 30-50 in hotels and 45-90 for residential floors, depending on the level of luxury. “We need to know all of these criteria right from the start, as once you fix the strategy, it’s very difficult to change it. We like to get involved when a project is still lines on the page, when people are talking about the business plan.”

VT strategies are evolving rapidly. In a supertall building, a strategy where separate banks of lifts serve groups of floors has traditionally proven to be the most efficient from both a passenger and space point of view, which can create a need for sky lobbies. Double-decker lifts have increased capacity and triple-decker versions are in development, while there are now “twin” cabins that move independently within the same shaft. There are also technologies that enable energy to be recovered from a lift’s counterweight and reused elsewhere, and advances in control technology allow passengers to input their destination in the lobby so that the system works out the ideal “flight profile” for each lift. The maximum number of floors that a single lift could serve used to be limited to 100 by the weight of its steel cables. But with the development of super-strength carbon-fibre belts, that has more than doubled to over 1,000m, a quantum leap that would allow a single lift to reach the uppermost levels of the Kingdom Tower. Manufacturers have even looked into developing lift cabins that move sideways between shafts as well as up and down. “As buildings get taller and taller, that challenges us all and makes us do a better job,” says Truss. “It’s exciting times from a lift design perspective.”

For him, vertical transportation is a passion as well as a job: “Any city in the world I go to, I will be riding lifts – my team all do the same thing because we love it.”

Vertically Yours

Credit: Nicola Evans, WSP Group
As the world gasps in wonder at one newly completed megatower, plans for an even taller one are unveiled ... It's a familiar story. The history of skyscrapers is defined by an irrepressible urge to build ever higher, more dazzling structures, and by the speed at which one world-record holder is superseded by the next. But how long will it go on? Can buildings really keep on getting taller forever?

“There is a limit – but it’s today’s limit, not a future limit,” says Jeff Smilow, director of building structures at WSP USA. Innovation and evolution in a whole range of technologies, from damper systems to high-strength materials, will enable designers to create higher and higher building structures. “There are always new technologies. If you talked to engineers 50 years ago or 70 years ago, you’d get a different answer than today.” What about a theoretical limit past which technology can’t take us? “You could find some very abstract limits on the strength of materials, but we are far away from reaching those limits,” adds Dr Ahmad Rahimian, director of building structures at WSP USA. “People’s aspiration, or the lack of it, is the real limit.”

In fact, it’s not a question of height so much as width. As buildings become taller, they must also get stronger and stiffer to remain stable in increasingly high winds. “You could easily build a building as tall as Mount Everest by making it as broad as Everest at the bottom,” says John Parker, senior technical director in London. Everest is 8,848m high, more than ten times taller than the Burj Khalifa. Even with a slenderness ratio of 24:1, equal to 111 West 57th Street, it would still be 368m wide at its narrowest point – almost as wide as the Empire State is high. Quite apart from the sheer amount of land required, there would be no access to daylight through much of the floorplate. Parker points out. “There’s a limit on how far from the window people would want to be.” Pumping water to the top, and sewage back down, would also test engineers’ ingenuity, as would pumping up the concrete for the structure itself.

And imagine how long it would take to get to the top. Vertical transportation is the other critical factor limiting a building’s height, and swelling its width. “The taller the building, the more lifts you need,” explains Parker. “The lifts can only go so far in one go because the cables will stretch, so you have to go up a certain distance, get out at a sky lobby and change to a different lift. The taller the building gets, the more lift changes you’ll have to make and the longer it’s going to take to get to the top floor. At some point, the guy who buys the penthouse is going to get fed up with spending 15 minutes to get to his front door.” Apart from the length of the journey, this also means a vast area is given over to VT. According to the traditional rule of thumb, a tower’s core accounts for around 20% of its area, so in a cylindrical Everest-sized tower, it would have to be at least 164m wide – roughly equivalent to the base of the Burj Khalifa. But that proportion also rises with height, says Parker. “A tower 8,500m tall would have a lower efficiency because the lifts and stability system would occupy much more than 20%. Which would mean an even larger chunk out of the usable, and crucially saleable, floor space.

This is the real crux of the matter: how many people would want to live, work or stay such a tall tower, and how much they are willing to pay for the privilege. “At the end of the day, height is limited by whether it’s economically viable,” says Rahimian. “The drivers for high-rise buildings are the fundamentals of the economy – how strong the market is, how much demand there is for the product.”

The Burj Khalifa was anticipated to be home or workplace for around 32,000 people. So a building ten times as tall might have a population of 320,000 – the same size as Iceland. We’re getting used to the idea of towers as vertical cities, but how long before we start thinking of them as vertical countries? •
Designed by Chetwoods Architects in collaboration with WSP, these twin towers are planned for the city of Wuhan in central China. They sit within a 47-hectare masterplan on an island in one of the city’s largest lakes, and provide not only a focal point for a 3km-long avenue but a range of environmental functions. The taller structure will stand 1km high, with multiple filtration systems to purify Wuhan’s air and lakes, as well as around 100 storeys of office, retail and residential space. The second tower includes a vast vertical garden, and leisure facilities such as restaurants, bars and galleries. The project was commissioned by China’s Hua Yan Group and completion is planned for in 2018.