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"Buildings within the urban environment are essentially pieces of refined geology, so when endeavouring to integrate plants into high-rise buildings, one must first observe plants that inhabit similar hostile environments in nature."

Godman et al., page 38

Americas

Fourteen years into its reconstruction, the World Trade Center area of **New York** continues to make headlines. **One World Trade Center**'s observation deck opened May 29, offering breathtaking sights from the United States' tallest building. The 387-meter-high observation deck is now the highest in New York and third-highest in North America. Elsewhere in the complex a new development brewed. The long-stalled **2 World Trade Center** project was revived, with Bjarke Ingels Group (BIG) replacing Foster + Partners as lead architect. The stacked design will incorporate prominent setbacks as it rises. The announcement was made in conjunction with the identification of News Corporation and some of its major media holdings, including 20th Century Fox, Fox News, and the Wall Street Journal, as the primary tenants. The original design was shelved as developer Silverstein Properties sought a sufficient threshold of financial commitment to complete the building. BIG's design will complete a spiral of gradually taller skyscrapers ringing the perimeter of the 6.5-hectare site, which was originally laid out by architect Daniel Libeskind in the redevelopment's master plan. It also promises to punctuate the Financial District's new economic identity, one that revolves around the media industry rather than finance.

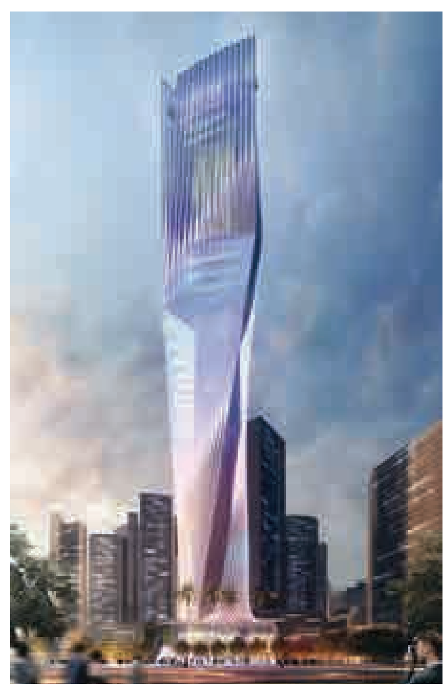
2 World Trade Center, New York. © BIG

Not all the New York news was downtown, however. The closely watched "superslim" race on 57th Street in Midtown intensified as drawings were released for the **Central Park Tower,** confirming that it will have the highest roof in the United States, at 464 meters, topping Chicago's Willis Tower by 22 meters. The spire of the building, formerly known as the Nordstrom Tower, however, will remain a tantalizing 0.3 meters shorter than the 541-meter spire of One World Trade Center.

Elsewhere in Midtown, the way was cleared for **One Vanderbilt Place,** a 64-story office tower just west of Grand Central Terminal, which received planning permission after a long rezoning battle that had stretched across two mayoral administrations. Just off Manhattan in the East River, a less lofty but no less important project got underway – an apartment tower on **Cornell University**'s new technology campus on Roosevelt Island will be the world's tallest passive-house high-rise when it completes in 2017. The building will conform to the rigorous Passivhaus standards established in Germany, which stipulate that the building is able to maintain a comfortable interior climate without active heating or cooling systems.

One Vanderbilt Place, New York. © KPF/DBox

Though it is best-known as a resort city, **Miami** is also a major technology hub on the global Internet trunk network in the United States, and its skyline is beginning to reflect this (see CTBUH Report, page 50). Plans for a four-block-square development, the **Miami Innovation District,** call for 358,000 square meters of office space, 223,00 square meters of housing, and 23,200 square meters of retail. Conceived as an "urban campus," the district is intended to create a focal point for Miami's tech industry, providing collaborative spaces and offices for startups alongside established companies and big global businesses. The centerpiece project, the 193-meter **Miami Innovation Tower,** is to feature a "fully integrated active skin" with displays built into the façade that will broadcast public announcements, video art, and advertising. Neighbors and the city's mayor



Miami Innovation Tower. © SHoP Architects oppose the tower's LED-festooned skin and have sought legislation to prohibit the feature.

Asian capital continues to flow into North American high-rise projects, as demonstrated by plans in cities as diverse as **Toronto, Las Vegas,** and **Los Angeles.** China's Greenland Group was set to break ground on the two-tower **King Blue Condominiums** in Toronto's Entertainment District, the first such investment by the company in a Canadian residential project. Another Chinese company, Shanghai's ShengLong Group, has unveiled plans for a US$100 million luxury high-rise residential tower near Staples Center in Los Angeles, the 37-story **1201 South Grand Avenue.** In Las Vegas, the first phase of the US$4 billion **Resorts World** scheme broke ground, driven by Malaysia's Genting Group. The four-tower project will eventually contain more than 6,500 rooms.

On a smaller scale, the Canadian city of **Quebec** nevertheless has big ambitions for tall timber. Plans were announced for the 13-story **Origine,** which would be built of cross-laminated timber and, at 40 meters high, take the title of tallest timber building in North America.

Origine, Quebec. © Yvan Blouin Architecture

On the opposite end of the country, **Vancouver** was set to host Canada's first project by Büro Ole Scheeren, **1500 West Georgia,** featuring a unique arrangement of stacked boxes. A system of vertically shifted apartment modules generates dynamic yet rational layouts for residential units, while the rotation of these elements projects individual living spaces outward, introducing the concept of horizontal living within a slender high-rise.

1500 West Georgia, Vancouver. © Büro Ole Scheeren

Asia and Oceania

Australia is grappling with the consequences of past decades' rapid rush into high-rise construction. The state of Victoria's building regulator has announced that every high-rise built in **Melbourne**'s central business district and inner suburbs in the past decade will be inspected for cheap, imported, non-compliant aluminum-composite cladding found to be flammable. The issue was expected to reverberate across the country and affect tens of thousands of buildings, presenting particularly high costs for retrofitting high-rises with difficult façade access.

Adding insult to injury, concrete spalling has been discovered in dozens of 40-plus-year-old **Gold Coast** apartment towers. Repair costs can run into the millions of dollars. The condition, also called "concrete cancer," results from salt-corroded rebar cracking the concrete that surrounds it, eventually compromising the building's structural integrity. One such building had to be demolished in 2013, and the problem has escalated since then, authorities say.

In other news, a local height limit was overturned in the Sydney suburb of **Parramatta,** clearing the way for the 306-meter **Aspire,** a hotel/residential tower that is

Aspire, Parramatta. © Grimshaw Architects

THEY SAID

"Carme Pinós reinvented the typology of the office tower with her brilliant Torre Cube, completed now almost a decade ago. That unique high-rise, bracketing trays of floor space between concrete cores, might truly be described as organic – a trio of arboreal trunks emerging up out of the ground and nesting office modules, like asymmetrical branches, screened by delicate timber slats."

Raymund Ryan, architectural journalist for Architectural Review discussing Cube II Tower in Guadalajara. From "Cube II Tower in Guadalajara, Mexico by Estudio Carme Pinós," Architectural Review, June 11, 2015.

For more on Torre Cube, see the CTBUH Technical Guide – *Natural Ventilation in High-Rise Office Buildings.* Visit CTBUH Web shop at **http://store.ctbuh.org.**

Two Towers, One Market

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The design of the new European Central Bank (ECB) in Frankfurt combines a twisted double tower, which rises to 185 meters, integrated with the horizontal structure of the landmarked 1928 Grossmarkthalle, formerly the city's main wholesale market. United by an entrance building, these two elements form an ensemble of special architectural significance. Featuring bridges, pathways and platforms, the glass atrium between the two high-rises creates a vertical city that represents the ambitions of a united Europe.

Design Concept: The Hyperboloid Cut

From the beginning, it was an explicit part of the brief from ECB to create a unique, iconic building as a symbol for the European Union. The designers felt such a goal could only be achieved by way of a completely different kind of geometry. The architectural concept of the ECB, therefore, is to vertically divide a monolithic block through a hyperboloid cut, wedge it apart, twist it, and fill the newly created intermediary space with several glass atriums (see Figure 1). The result is a very complex geometry, and a multifaceted building offering a completely different appearance from each angle: massive and powerful from the southeast (see Figure 2), slender and dynamic from the west (see Figure 3).

The Office Towers

The two towers house the vast majority of nearly 2,900 workstations at the new premises, as well as internal meeting rooms. The large council meeting room and the offices of members of the ECB's decision-making bodies are located on the upper office floors. All floors offer a high level of flexibility, to allow for a variety of office configurations, from single offices to larger offices that can accommodate 10 to 12 people. The offices are located along the outer façades of the towers, and on every floor there is a kitchenette and communal area.

The Principle of the "Vertical City"

The concept behind the glazed atrium between the two office towers is one of a "vertical city," with interchange platforms and bridges creating the impression of urban streets and squares. The exceptional atrium and

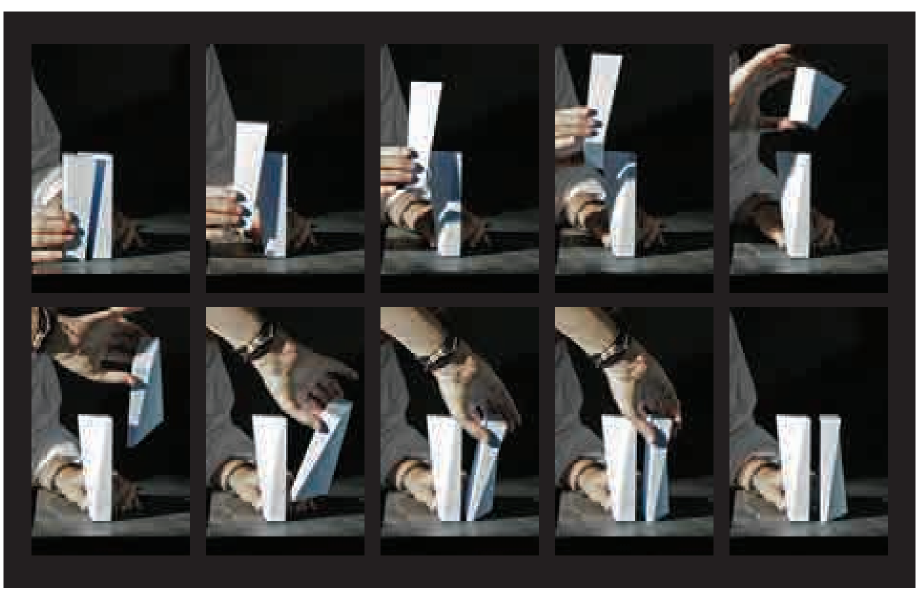

Figure 1. ECB design concept study.

Figure 2. View from the southeast. © Paul Raftery

visible steel support structure place the ECB building within an entirely new typology of skyscrapers. The interchange platforms enable people to change from the express elevators to the local elevators. They can be reached via sets of stairs leading from the respective floors above and below, making it easy for staff to move between the two towers and communicate with each other informally.

The connecting and transitioning levels divide the atrium horizontally into three sections with heights from 45 to 60 meters (see Figures 4 and 5). This is where all vertical entry points are joined – and just like public squares, they invite visitors to communicate. The planned "hanging gardens" will ensure a pleasant room climate, while elevators and stairs connect these places with the offices and communication areas of the Grossmarkthalle.

The Grossmarkthalle as "Urban Foyer"

The semi-public and communicative functions are located in the former Grossmarkthalle. In addition to fulfilling numerous functional and technical requirements, the architects were required to retain the fundamental appearance of the Grossmarkthalle, a listed building, and incorporate it into their designs for the new ECB premises. The existing landmark Grossmarkthalle, a former wholesale market from the 1920s, is used as an "urban foyer." The conference and visitor's center, library, and employee cafeteria are placed diagonally in the spacious interior of the hall as independent building structures (executing a "house within a house" concept) (see Figure 6).

The Entrance Building

A floating entrance building penetrates the hall structure from the outside, creating an aesthetic and functional link between the office tower and the Grossmarkthalle. With its asymmetrical contours, slanted façades, and generous windows, it marks the representative access to the ECB from the north of the site. The lobby, two-story press conference room, and a lecture room are located here. The press center is accessible via its own lobby, above

Figure 3. European Central Bank – overall view. © Paul Raftery

"The concept behind the glazed atrium between the two office towers is one of a "vertical city," with interchange platforms and bridges creating the impression of urban streets and squares."

Climate Change in Hong Kong: Mitigation Through Sustainable Retrofitting


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Recent reports by the Intergovernmental Panel on Climate Change (IPCC) have raised public awareness of energy use and its environmental implications. There are more than 41,000 existing tall building blocks in Hong Kong. Future projections indicate that the total number of buildings in 2050 will increase to around 58,000, at a rate of 450 buildings per year. A five-step survival strategy has been developed to aid the formulation of sustainable retrofit initiatives for the existing building stock, and to investigate long-term building energy performance under the impact of climate change. A LEED-certified existing commercial office building in Hong Kong retrofitted with these survival strategies is presented here, and the impact of climate change on future building energy use in Hong Kong is investigated.

Review of Hong Kong Electricity Use

Over the past three decades, Hong Kong has seen a significant increase in energy consumption, especially during the economic expansion of the 1980s and early 1990s. Primary energy requirements (PER) rose from 195,405 TJ in 1979 to 601,544 TJ in 2014, representing an average annual growth rate of about 3.2%.[1] Most of the PER (represented by coal, natural gas, and oil products) was used for electricity generation, which accounted for 63.3% of the total PER in 2014. The commercial sector was the largest component of consumption, accounting for 66% of the total electricity consumption in 2014. Figure 1 shows the monthly electricity consumption in the commercial sector during 1979–2012.[2]

A significant proportion of this consumption was due to the ever-growing demand for better thermal comfort, especially in terms of air conditioning during the hot, humid summer months (Lam et al. 2003 & 2004). In subtropical Hong Kong, winter is short and mild, and summer is long, hot, and humid. For commercial premises with high internal heat gains from occupants and equipment, air conditioning operates all year round (Lam 1995 & Lam et al. 2009). It was found that about 10% of the total electricity consumption was for air conditioning outside the main cooling period of March to November. Based on this assumption, monthly electricity use for air conditioning was determined, and is also shown in Figure 1. Air conditioning consumption rose from 1,120 GWh in 1979 to 8,521 GWh in 2012 (a nearly eight-fold increase) and accounted for approximately 30% of the total electricity use in the commercial sector. This is consistent with the 29–32% increase published in the Hong Kong Energy End-use Data (EMSD 2008).

Existing Buildings in Hong Kong

Buildings account for most of the region's electricity consumption (e.g., 90% in Hong Kong) and energy consumption in buildings is responsible for approximately 60% of greenhouse gas (GHG) emissions in Hong Kong (Environment Bureau 2010). Figure 2 indicates the total constructed floor area (in thousands of square meters) of residential and nonresidential buildings from 1970–2013 in Hong Kong. An increasing trend for new building construction can be observed since 1970, peaking in 1991 and followed by a downturn. In 2010, existing buildings aged 20 years or more represented 50% of the building

[1] *Hong Kong Energy Statistics Annual Report.* Census and Statistics Department, Hong Kong SAR, 1979–2008. http://www.censtatd.gov.hk.
[2] *Hong Kong Monthly Digest of Statistics.* Census and Statistics Department, Hong Kong SAR, 1979–2012. http://www.censtatd.gov.hk.

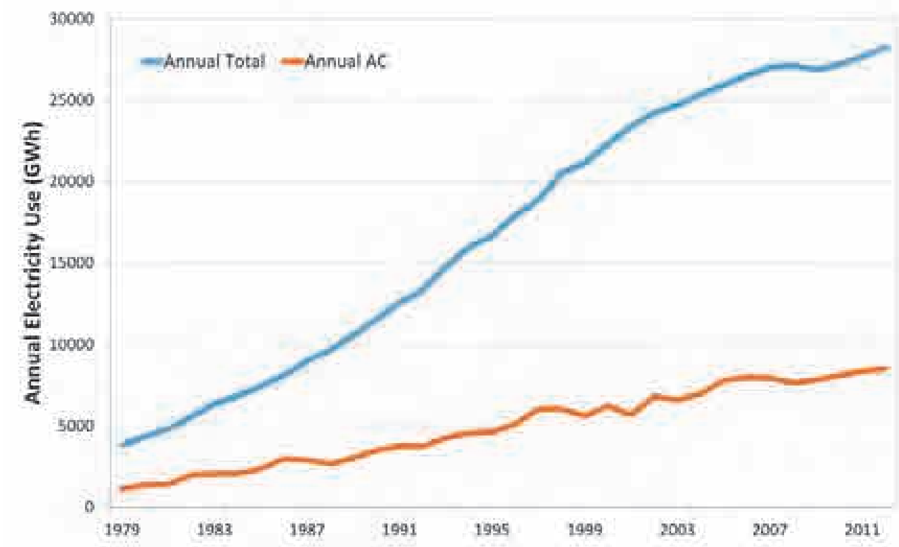

Figure 1. Monthly electricity use in the Hong Kong commercial sector (1979–2012).

stock, and 30-year-old-plus buildings represented more than 20%.

Figure 3 shows that the total building number in 2050 would be increased to around 58,000, representing a growth rate of 450 buildings per year. Existing buildings will continuously undergo replacement and refurbishment. By 2020, it is envisaged that 14% (5,600) of the existing buildings will require refurbishment or replacement, rising to 26% (10,400) in 2030 and 44% (17,600) in 2050. There is significant potential for building retrofitting as a means of preservation and avoiding greater carbon release as a result of demolition and new construction that would otherwise occur.

Carbon Emissions Reduction Targets

Buildings typically have a long life span, lasting for 50 years or more, and they account for more than a third of global greenhouse gas emissions (Guan 2009). It is therefore, important to be able to analyze how buildings will respond to climate change in the future, and assess the likely changes in energy use.

In September 2010 the Environmental Bureau in Hong Kong announced the latest plan to combat climate change, committing to reduce its carbon intensity by 50–60% by 2020 against a 2005 baseline. This translates to an absolute annual emission reduction of 28–34 million metric tons of CO_2 in 2020, or a 12–18-metric-ton reduction from business-as-usual growth (C&SD 2013). It is envisaged that existing buildings with good energy performance could help to reduce electricity use as well as carbon emissions significantly. However, designing optimal strategies that can help retrofitted buildings survive under the scenarios of climate change is the challenge. This paper formulates the survival strategies for retrofitting high-rise buildings and investigate the impact of climate change on a sustainable retrofitted building project in Hong Kong.

Sustainable Tall Building Design: Survival Strategies

Existing buildings are part of a city's heritage, and their significance in energy consumption should not be overlooked. A five-step process has been developed to aid the formulation of sustainable retrofit strategies and investigate building quality on a long-term basis under the specter of future climate change (Arup & PCA 2008, China Resources Property Limited 2014).

Step 1: Baseline establishment
For every building retrofit project, it is important to set up the baseline before determining any upgrade strategy. To establish the baseline, key performance indicators (KPI) can be obtained through conducting audits on various aspects, including energy consumption, occupant satisfaction, facilities management operation, and the condition of the building. Other baselines might include water consumption, waste generation, and Indoor Environmental Quality (IEQ). Audit results can be compared against benchmarks to determine opportunities for improvement.

Step 2: Review of the existing building designs and maintenance records
Effective property maintenance is essential to the efficient operation of buildings. Facilities Management (FM) contracts are well-executed in many instances, but lack regular reviews. As such, opportunities to maximize savings and optimize performance tend to be overlooked.

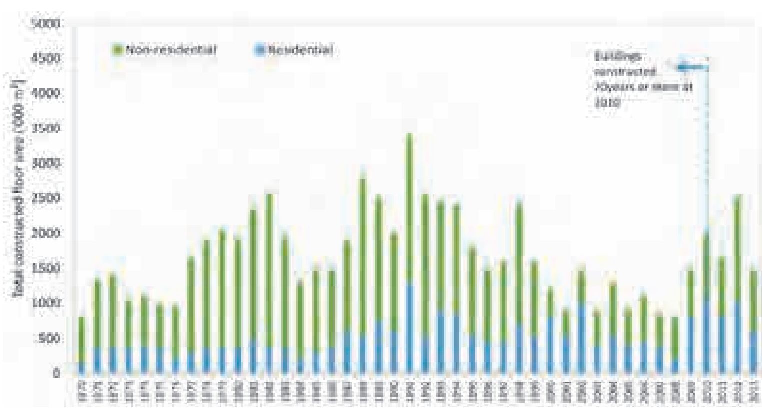

Figure 2. Constructed buildings in Hong Kong during 1970–2013.

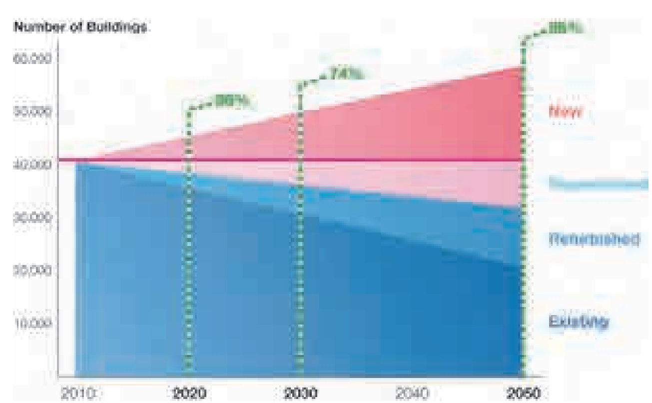

Figure 3. Projection of the variations in building mix in Hong Kong.

Fire Safety Strategies for Penthouse Designs

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Penthouses, with their luxurious amenities and uninterrupted 360-degree views over the city skyline, tend to be larger than normal apartments and often have unique design features that can create challenges in fire safety design. The critical questions are: can occupants escape safely from the top of a high-rise tower, and what are the conditions within the penthouse once the Fire Brigade has arrived at the top of the tower? This article outlines the fire safety strategy for a unique five-story open-plan penthouse in London. A fire engineering assessment was required, including the use of CFD simulations, to prove that the proposed design complies with the functional requirements of building regulations in the United Kingdom.

Introduction

Since the first penthouse apartments were built in New York City in the 1920s, penthouses have been popular and continue to carry a sought-after prestige in capital cities around the world. One Hyde Park's penthouse in London recently sold for US$208 million (Huffington Post 2014) and the penthouse in Monaco's New Odeon Tower is expected to sell for at least US$386 million (The Guardian 2014). Penthouses, with their luxurious amenities and uninterrupted 360-degree views over the city skyline, give the feeling of being located away from the city, as they are generally less noisy than apartments on lower floors. They also tend to be larger than normal apartments, sometimes accessed by a private elevator opening directly into the apartment. They can come equipped with a private terrace, a private pool, or other unique features.

A recent example of a unique penthouse apartment is the five-story penthouse on top of the 36-story 261 City Road development located in Islington, London. The development is composed of three buildings (Buildings A, B, and C), all designed by Skidmore, Owings & Merrill (SOM). Buildings A and C are both seven-story buildings served by two stairs, while Building B, also known as the Lexicon, is a single-stairway building with a height of 118 meters, and will be the tallest building in the area (see Figures 1 and 2). The development will offer more than 300 residences (both private and affordable units), amenities such as a spa, retail space, and a public courtyard, as well as a restaurant at ground floor level in front of the newly created City Road basin.

As penthouses are one-of-a-kind apartments with specific features and layouts, giving flexibility to the architect can be a challenge due to fire safety restrictions in many jurisdictions. In the United Kingdom, for example, justifying an open-plan layout is generally done through a fire engineering assessment, the principles of which, including evacuation time calculation and Computational Fluid Dynamics (CFD) modeling, are explained in this paper.

Figure 1. 261 City Road, London – overall view. © Mount Anvil

General Fire Safety Strategy

The general fire safety strategy for the development under study here was based on recommendations within Approved Document B (ADB) (DCLG 2013), which is the most common fire guidance in use in England and Wales. Buildings A and C are less than 30 meters in height, so the minimum fire resistance of the main structure is set at 90 minutes. Building B has 120 minutes' structural fire resistance, due to its height being greater than 30 meters, and is fitted with a sprinkler system throughout. Dry risers are provided to buildings A and C, while Building B has a wet riser.

All the buildings are greater than 18 meters in height, and therefore are all fitted with a firefighting shaft – consisting of a ventilated firefighting stair, a fire main provided at every level within the stair core, a firefighting lift provided with emergency back-up power supplies; and a firefighting lobby, which is the ventilated residential common corridor. The common corridor in Building B is mechanically ventilated via a 0.6-square-meter smoke shaft, while Buildings A and C use the 1.5-square-meter natural smoke shaft recommended within ADB. Finally, a conventional "defend in place" strategy is adopted for the residential levels, where only the occupants from the apartment of fire origin evacuate. This is a standard assumption for residential developments in the United Kingdom, as the neighbors, protected by a high level of fire compartmentation (at least 60 minutes' fire resistance), remain in place. In the case of Building B, each floor is also separated by 120 minutes' fire resistance.

ADB can be restrictive in terms of apartment layouts, as it generally requires all the habitable rooms to be approached via a sterile, 30-minutes fire-resistant, protected entrance hall with FD20 fire doors. Guidance within British Standard (BS) 9991:2011 (BSI 2011) offers more flexibility and allows open-plan apartments under certain conditions, such as a ceiling height above 2.25 meters, enhanced fire alarm and detection systems (i.e., one detector in every room), and a residential sprinkler system fitted throughout the apartment. When the dimensions of the apartments are greater than the maximum size allowed within BS 9991, or if it is a multi-level open-plan apartment, a fire-engineered assessment is generally used to justify the layout, by

Figure 2. Lexicon, London under construction. © Mount Anvil

determining the conditions within the proposed apartments in case of fire, and by demonstrating an adequate level of safety for the occupants. Following this approach, several apartments within the development had to be fire-engineered, including the use of CFD modeling, with the most challenging apartment being the five-story open-plan penthouse sitting on top of Building B at more than 100 meters above grade.

The Penthouse

Geometry

The 385-square-meter penthouse (see Figure 3) is composed of five stories with:

- The entrance and reception lounge at Level 32;
- The kitchen and living room at Level 33;
- Bedrooms at Levels 34 and 35; and
- A roof terrace at Level 36.

Two stairs are provided within the penthouse: one open stair located within a void between Level 32 and Level 33, and another linking Level 33 to the upper floors. Additional measures include a residential sprinkler system, enhanced fire alarm and detection system, and an automatic openable vent (AOV) on top of the stair linking Levels 33, 34, 35, and 36. The penthouse has a height of 15 meters between the slab at Level 32 and the ceiling above the stair at Level 36.

Fire-engineered assessment

Due to the uniqueness of this five-story penthouse, it was considered to be more closely related to a "dwelling house" than to an apartment. Dwelling houses with more than one floor over 4.5 meters above ground floor level (typically a dwelling house of four or more stories), would typically require:

- A protected stair and a sprinkler system throughout; or
- A protected stair and an alternative means of escape for any level above 7.5 meters

The sprinklered penthouse in this study has been designed with open internal stairs, instead of the recommended protected stair, and no alternative means of escape has been provided. A fire-engineered assessment, based on a deterministic study, has therefore been used to establish if occupants asleep on the terrace at Level 36 would be able to escape safely during two different fire scenarios, via the open internal stairs to the entrance door at Level 32, before conditions

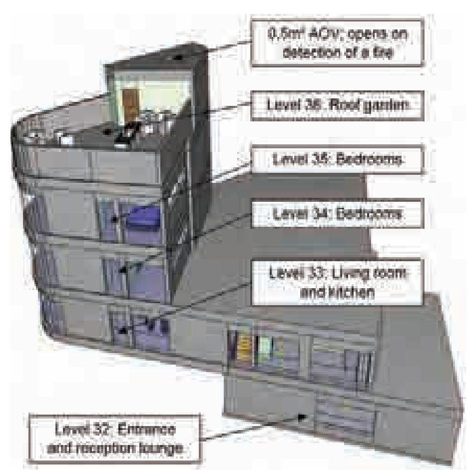

Figure 3. 3D geometry of the penthouse.

Istanbul: Impact of High-Rises on a Historic, Yet Contemporary, City

Ayşin Sev

Bahar Başarır

High-rise buildings have a significant impact on cities and their metropolitan areas in a variety of ways, most notably on cities with extensive historic built heritage, like Istanbul. Many of these buildings can be regarded as iconic structures, constructed using state-of-the-art technologies and demonstrating the economic power of the city and the country. Using Istanbul as an example, this paper discusses the role of high-rise buildings, their effect on inhabitants' lives, and drivers of the high-rise boom in historic cities, regardless of the contentious necessity of high-rise buildings in an urban environment.

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Introduction

Behind the ambition to build tall is the symbolic and iconic value of the tower, which is closely related to the wealth and power of nations. A high-rise building is without a doubt a significant symbol of a city. Although it may cause problems in the urban context, developing cities compete with each other on the global stage to have the tallest and most iconic high-rise buildings in the world. Acting as symbols of economic activity, high-rise buildings are often seen as beacons of economic and political power (Kostoff 2001). They also have the capacity to capture public imagination (Höweler 2003). No matter what their functions are, they cannot be ignored (Abel 2003). The introduction of a new, large-scale building into a city is an intervention within the existing urban context, one which alters the preexisting urban conditions.

Having a traditional skyline, Istanbul's character has been strongly impacted by the erection of high-rise buildings in the past few decades, whether these have been built in the historic core or not (see Figure 1). It is unfortunate that many recently erected high-rise buildings, especially in the Bosporus region, are not in harmony with the silhouette of Istanbul. Even though they are some distance from the historic core, some of the high-rise buildings negatively impact the historical silhouette due to the special topographic character of the city. This paper discusses the impacts of high-rise buildings on the built heritage and historical skyline of the city, and presents how the historical silhouette of Istanbul has changed over time. Additionally, the conditions that have led to the construction of high-rise buildings in the region, and their effect on city inhabitants and infrastructure are described.

Istanbul's Unique Context

Istanbul, located in the northwest of Turkey within the Marmara region, is a highly developed city with a Mediterranean climate. The geography of the city is hilly, with several high peaks. The Bosporus Strait, which connects the Sea of Marmara to the Black Sea, divides the city into the European and Anatolian (Asian) sides, making Istanbul the

Figure 1. The skyline of Istanbul oriented by contemporary high-rise buildings.

only bicontinental city in the world. The European part of the city is further divided by the Golden Horn, a natural harbor bounding the Peninsula, where the former Byzantium and Constantinople were founded.

The city has sustained massive population growth. In 1950, it had a population of 1,116,477 residents. The number of citizens almost tripled during the 30 years between 1980 and 2010, and it currently has a population of 14,377,018 residents, in an area of 5,343 square kilometers, according to the Turkish Statistical Institute (TUIK 2014). The rate of annual population growth in the city is currently 1.55–2%, mostly due to migration from the rural areas of the country. The population density is 2,767 people/km^2, which far exceeds Turkey's overall population density of 101 people/km^2.

Development of Istanbul's skyline

Istanbul, with its strategic location on the Bosporus peninsula, has been associated with major political, religious, and artistic events for more than 2,000 years. The city served as a capital for the Eastern Roman, Byzantine, and Ottoman empires. The outstanding universal value of Istanbul, based on its unique integration of architectural masterpieces, reflects the meeting of Europe and Asia over many centuries, represented by its incomparable historic skyline, formed by Byzantine and Ottoman architecture. The skyline was built up over many centuries and encompasses the Hagia Sophia, which reflects the architectural and decorative expertise of the 6th century, the Fatih complex, the Topkapi Palace, the Süleymaniye Mosque complex, and the Sehzade Mosque complex, which reflect the climax of Ottoman architecture in the 16th century. The Blue Mosque and the slender minarets of the New Mosque were completed in the 17th century (see Figure 2).

The historic roots of the dominant vernacular architecture in Istanbul go back to attitudes about modernization and rapid urbanization that developed in the 20th century. With the establishment of the Turkish Republic and the transfer of administrative functions to Ankara in 1923, the city lost its importance for a while, and its population decreased to 650,000 in 1923 – only half its population in 1914. Consequently, the government was forced to rethink the urban planning of Istanbul. The French architect and town planner Leon Hénri Prost (1874–1959), who was responsible for the Paris Regional Plan of 1928–1939, was brought in to design the Istanbul Master Plan (1936–1958). Prost's planning approach was to build large roads and boulevards, and destroy the old city fabric, which he considered unsuitable for a modern nation. The construction of new residential blocks started the city's reshaping, which created differentiation in terms of building hierarchy and organization (Tekeli 2010). Rapid, initially uncontrolled urbanization and the threat of pollution arising from industrialization jeopardized the historical and cultural heritage of the old city center.

Figure 2. The historical skyline of Istanbul oriented by minarets and domes. © Salih K.

High-rise building construction in Istanbul

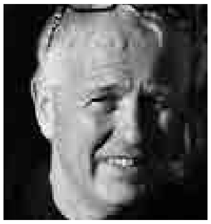
High-rise building construction, which is occurring at a rapid pace in many cities of the world, has also accelerated in Istanbul. High-rise building construction entered the agenda of the city in the 1950s. One of the significant barriers to the first wave of construction in Istanbul was its seismicity; the city is located on the North Anatolian Fault. Despite this barrier, the rapid population growth that began in the 1950s has been an instrumental factor in spurring high-rise building construction in Istanbul. Table 1 shows the rapid population growth in the city. Through the second half of the 20th century, the city's sociocultural and political importance grew, its economy expanded, and many institutions underwent changes in scale, context, and appearance. Buildings that reflected technological progress and the fashionable architectural trends of the day endowed the city with a new urban landscape and new image (Batur 1996). New forms of urban development, such as apartment ownership and housing cooperatives, also led the city's expansion to new areas. From the beginning of the 1950s to the mid-1970s, high-rise hotels and office buildings averaging 25 stories in height were built in Turkey (Usta & Usta 1995). Istanbul also saw the construction of a handful of high-rise buildings of less than 20 stories by the early 1970s, including the 17-story Marmara Etap Hotel, the 21-story Odakule Office Building, and the 17-story Karayollari Headquarters.

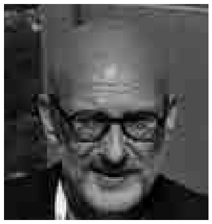
The late 1970s and 1980s saw an escalating number of high-rise buildings with more than 20 stories. The commercial district of the city moved towards Besiktas, Zincirlikuyu, and Maslak from Eminönü, the first business district. New urban centers, occupied by multinational businesses, were developed. New programs and needs drove changes in the architecture. At the beginning of the

Years	Population of Istanbul	Population of Turkey	Istanbul population as % of Turkey
1950	1,116,477	20,947,188	5.33
1955	1,533,822	24,064,763	6.37
1960	1,822,092	27,754,820	6.57
1965	2,293,823	31,391,421	7.31
1970	3,019,032	35,605,176	8.48
1975	3,904,588	40,347,719	9.68
1980	4,741,890	44,736,957	10.60
1985	5,842,985	50,664,458	11.53
1990	7,309,190	56,473,035	12.94
2000	10,018,735	67,803,927	14.78
2010	12,782,960	73,722,988	17.98
2014	14,377,018	77,695,904	18.50

Table 1. Population growth in Istanbul and Turkey. Source: Turkish Statistical Institute 2015.

A "Flight Manual" for Air Plants


Lloyd Godman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Lloyd Godman is an ecological artist and has an MFA from RMIT University, Melbourne. He has had more than 45 solo exhibitions and been included in more than 250 group exhibitions. His current work explores living plant works and "super-sustainable" art. In 2011, he began creating suspended rotating plant sculptures and since then has worked with plants on tall buildings, including Eureka Tower, Melbourne.

Stuart Jones has recently been appointed Technical Director for Hyder Consulting in Melbourne. Previous to this he was the Owner/Director of Point 5 Consulting in Melbourne for 14 years. Stuart has over 25 years' professional experience in all phases of project delivery and specializes in creative structural design, with extensive experience in Australia and throughout Asia.

Grant Harris is the principal of Ironbark Environmental Arboriculture, with more than 12 years' experience in the arboricultural sector. He also holds a degree in Environmental Science (Wildlife and Conservation Biology). His particular areas of interest are the use of green infrastructure to mitigate urban heat island effects and urban ecology.

The green fabric that clothes the earth is fraying. Sadly, through overuse, the garment we depend upon is wearing out. The construction of buildings and urban infrastructure like roads and car parks become "dead pixels" in the living image of the planet. Repairing the old garment by stitching plants into the structures of our cities is a vital option. Incorporating plants into tall building design is an important aspect of this restoration project. This paper describes the successful installation of plants on the exterior of Melbourne's iconic Eureka Tower (see Figure 1) and provides an example of a selective vertical gardening system with a high Environmentally Sustainable Development (ESD) factor, which eliminates the requirement for plant growth substrate.

The Importance of Vertical Gardens

From simple organisms, evolving through millions of years to complex biological systems, vegetation has obeyed its innate compulsion to cover the planet with a living green membrane that supports all other life. Plants have waxed and waned in their fight to cover geological surface since the Ordovician period (495 million years ago), and as we progress through our current era, the Anthropocene, it is evident that human actions are the primary determinant for the survival or extinction of species. The exponential rate at which our cities have expanded demands that we now plan and act to integrate our urban centers into the biosphere of the planet. The combined surface of high-rise buildings and other urban infrastructure can provide significant areas to support plants, and weave back the threads of green fabric.

Integrating plants into the built environment improves air quality, moderates temperatures (Saadatian et al. 2013), improves human well-being, lifts the spirit (Townsend & Weerasuriya 2010), and can provide habitat for other species (Oberndorfer et al. 2007). In March 2015, it was promising to see a law passed in France, which mandates that rooftops on new buildings built in commercial zones must either be partially covered in plants or solar panels. This mandate draws a line, whereby inspiring contemporary architecture will be measured by the successful integration of living green texture into the fabric and form of the structure. Imagination and experimentation have driven a welcome expansion of roof and vertical gardens in recent years. The urbane tall buildings we now see may quickly become historic symbols of a past age, when architecture was less connected to nature.

Vertical Garden Systems

Utilizing living plants as an effective façade poses many problems. Unlike metals, glass and concrete, which are inert, plants require nurturing. Concerns over increased maintenance costs (Zhang et al. 2012), damage to façades, and increased loading on structural systems (Wood et al. 2014) are barriers to the implementation of green roofs and walls. Zhang et al. provide a succinct definition of "intensive" and "extensive" green roof systems.

Intensive green roof systems are characterized by deep (greater than 15 centimeters) growing media, opportunities for a diverse plant palate on the rooftop, and high maintenance requirements. In many cases, intensive green roofs are being replaced by *extensive* green roofs, which have a much thinner, lighter media (thus fewer structural requirements), and offer fewer, but potentially more practical plant choices.

Building on Zhang's categorization of green roofs, the authors propose that incorporating vertical gardens into a building's design can employ two systems, which are adaptive or selective.

Adaptive systems

Analogous to intensive green roofs, adaptive vertical gardens require the environment to be adapted to support the plants' biological demands, which will vary depending on the ecophysiological characteristics of the selected species. This condition is met by mesh-mounted plant growth substrate, irrigation and fertilization. The benefit of adaptive systems is that they allow a greater selection of species; however, they have limitations, including the cost of installing and maintaining structures to support plant growth substrates (Pérez et al. 2011).

Selective systems

Akin to extensive green roofs, selective systems use critical species selection to identify plants that naturally grow in environments similar to those encompassing an existing building's façade. They have the advantage of reducing or eliminating the requirement for plant growth substrate and associated installation and maintenance costs. The limitation of selective systems is a reduced plant palette.

Plant Selection

Epiphytic plants are those that use other plants for mechanical support; a diversity of plant groups has evolved to fill this environmental niche. Life as an epiphyte, high in the forest canopy, exposes the plant to greater fluctuations in moisture availability in comparison to their terrestrial cousins, nestled comfortably in the soil below. Tillandsia (see Figure 2), which is a genus of the Bromeliad family, includes more than 1,000 epiphytic species (Benzing 1990) that have evolved to have no requirement for soil and tolerance of extremes in moisture availability. Both of these are attractive characteristics when choosing plants for utilization in a selective vertical garden system.

Tall buildings present an extremely challenging environment for plant growth, where consistently high wind speeds increase transpirational losses and thereby increase water stress on plants growing in these environments. *Tillandsia bereri* and a hybrid, Houston, were selected to test the concept of a selective vertical garden system because they have the following characteristics:

Drought tolerance

Bromeliads minimize transpirational water losses by utilizing the crassulucean acid metabolism (CAM) cycle, in which the stomata are closed in the heat of the day and open to uptake CO_2 at night, releasing oxygen during darkness (Benzing 1990). Moisture and nutrient uptake occur through specialized trichome cells, further reducing transpirational water losses; these adaptations make Tillandsia very drought-tolerant.

No requirement for soil

One adaptation of Tillandsias to the epiphytic life-mode is the modification of the role of the roots from that of moisture and nutrient absorption to that of "hold-fasts" that function only to attach the plant to the substrate (Benzing 1990). The leaves of the plant replace the role of the roots and sequester moisture and nutrients directly from the atmosphere,


Figure 1. Eureka Tower, Melbourne. © John Gollings

leading to the colloquial name of "air plant." This adaptation removes the requirement for a plant growth substrate to be installed on the building façade. The lack of water-seeking roots also negates building managers' concerns about potential damage and maintenance costs.

Absorption of airborne pollutants

The trichomes of Tillandsia have a high absorptive capacity, which allows them to absorb air pollutants rapidly (Li et al. 2015). The installation of large Tillandsia screens on tall buildings has the potential to act as an air filter for the building and surroundings.

Minimal weight

Based on previous installations, the weight of a Tillandsia screen is estimated to be 3 kg/m^2, which is minimal in comparison to adaptive systems that require plant growth substrates and supporting structures. The light weight of Tillandsia means they are perfectly suited for use on screens (Pérez 2011) and can be placed in arbitrary shapes on the building


Figure 2. Tillandsias, the "air plants" chosen for the experiment.

> "The leaves of the Tillandsia sequester moisture and nutrients directly from the atmosphere, removing the requirement for a plant growth substrate to be installed on the building façade."

World's Highest Observation Decks

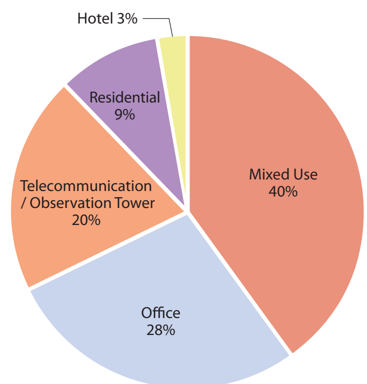
Perhaps no element of a tall building is more closely related to the pure pleasure of standing high in the sky and taking in the view of one's surroundings than observation decks. Often adding an important source of revenue for the structures that have them, observation decks also change the way people view cities, and can potentially elevate their international reputation. However, many operators don't take the "pure pleasure of height" for granted, choosing to include all manner of amusements, from glass floors to roller coasters and bungee jumps. Here we take a look at the history and chronicle some of the histrionics of humanity's obsession with height.

The history of the observation deck can be said to have its origins in North American culture, and the observation deck was integrated into the skyscraper at an early stage. As soon as we started building into the clouds, people wanted to know what the view looked like from the top. Recently however, Asia and the Middle East have taken over the development of the observation deck as they come into their era of building tall.

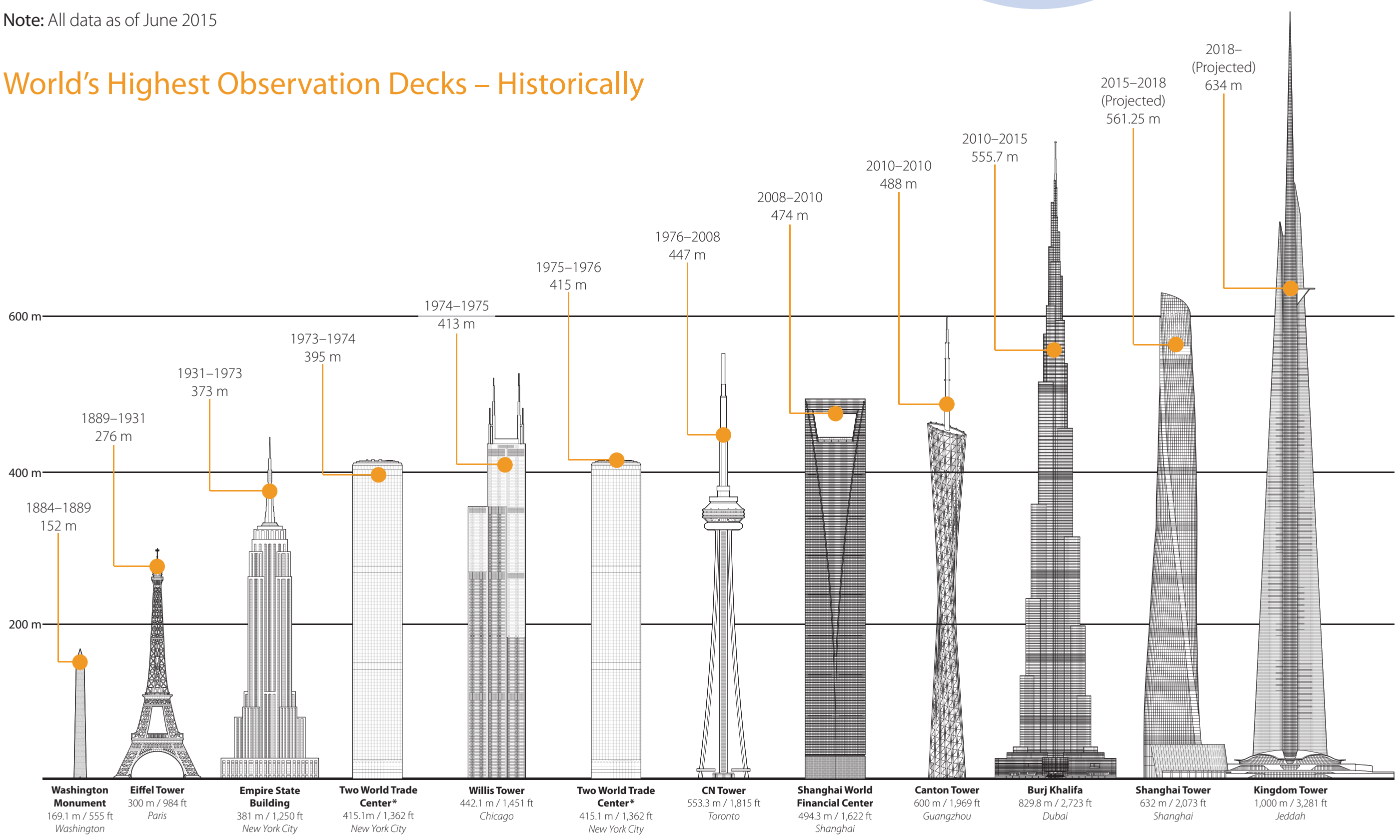
Note: All data as of June 2015

Observation Decks by Function

This figure shows a breakdown of the uses within the 75 tallest structures in the world with observation decks.



World's Highest Observation Decks – Historically



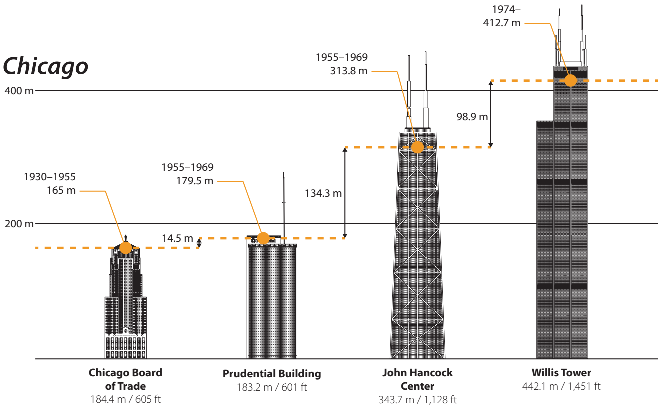
*Two World Trade Center, New York City, is featured on this historical skyline twice. After the original observation deck (395 meters), was surpassed by the observation deck at Willis Tower, Chicago (413 meters) in 1974, Two World Trade Center opened a new, higher observation deck on its roof (415 meters), once again making it the tallest observation deck in the world.

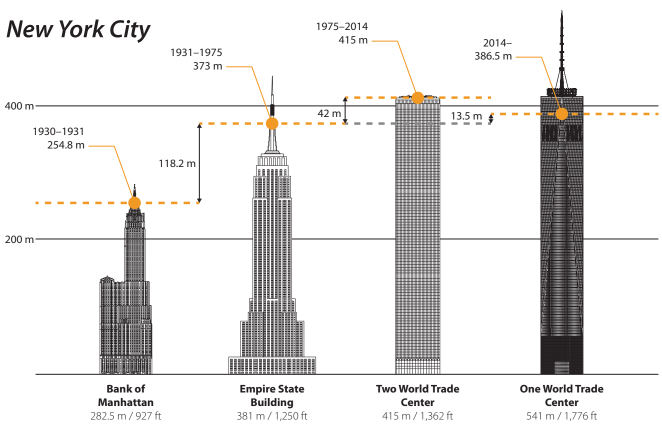
The Eiffel Tower, Paris, has the most visited observation deck in the world, averaging six million visitors every year

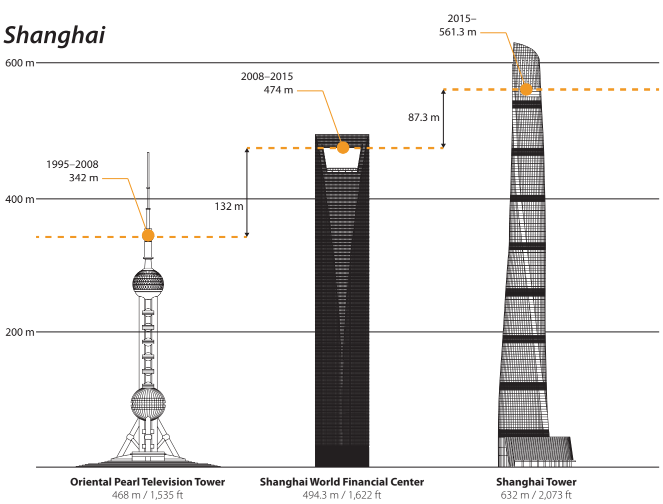
Willis Tower has The Ledge, John Hancock Center has Tilt!; both thrill visitors with nothing but glass between them and a view of the ground

From the Empire State Building observation deck, it is possible to see across four state lines to New Jersey, Connecticut, Pennsylvania, and Massachusetts

Historic Increases in Observatory Height by City







The World's 75 Highest Observation Decks

Ranked by observation deck height, the following table lists the location and height of the 75 tallest observation decks in the world that have either been completed (shaded), or are currently under construction (unshaded).

No	Building	City	Observation Height (m)	Architectural Height (m)	Completion
1	Kingdom Tower	Jeddah	637.5	1,000	2018
2	Suzhou Zhongnan Center	Suzhou	592.8	729	2020
3	Goldin Finance 117	Tianjin	578.7	596.6	2016
4	Wuhan Greenland Center	Wuhan	567	636	2017
5	Shanghai Tower	Shanghai	561.3	632	2015
6	Burj Khalifa	Dubai	555.7	828	2010
7	Ping An Finance Center	Shenzhen	550	660	2016
8	China Zun Tower	Beijing	503.5	528	2018
9	Lotte World Tower	Seoul	497.6	554.6	2016
10	Makkah Royal Clock Tower	Mecca	484.4	601	2012
11	Canton Tower	Guangzhou	448	600	2010
12	Shanghai World Financial Center	Shanghai	474	492	2008
13	Tokyo Sky Tree	Tokyo	451.2	634	2012
14	CN Tower	Toronto	447	553.3	1976
15	Chongqing International Trade and Commerce Center 1	Chongqing	440	468	2019
16	KK100	Shenzhen	427.1	441.8	2011
17	Guangzhou International Finance Center	Guangzhou	415.1	439	2010
18	Willis Tower	Chicago	412.7	442.1	1974
19	Dalian Greenland Center	Dalian	406.5	518	2018
20	TAIPEI 101	Taipei	391.8	508	2004
21	International Commerce Center	Hong Kong	387.8	484	2010
22	One World Trade Center	New York City	386.5	541.3	2014
23	Marina 106	Dubai	378	445	2018
24	Marina 101	Dubai	375	426.5	2015
25	Empire State Building	New York City	373.1	381	1931
26	Petronas Tower 2	Kuala Lumpur	370	451.9	1998
27	Princess Tower	Dubai	356.9	413.4	1998
28	Lakhta Center	St. Petersburg	353.3	462	2019
29	Oriental Pearl Television Tower	Shanghai	342	468	1995
30	T & C Tower	Kaohsiung	341	347.5	1997
31	Jin Mao Tower	Shanghai	340.1	420.5	1999
32	Ostankino Tower	Moscow	337	540	1967
33	30 Hudson Yards	New York City	336	386.5	2019
34	Longxi International Hotel	Jiangyin	315	328	2011
35	John Hancock Center	Chicago	313.8	343.7	1969
36	Tianjin World Financial Center	Tianjin	313.6	336.9	2011
37	China World Tower	Beijing	311.8	330	2010
38	Stalnaya Vershina	Moscow	306.8	308.9	2015
39	World One	Mumbai	304.8	442	2016
40	The Torch	Dubai	303.6	352	2011
41	KAFD World Trade Center	Riyadh	300	303	2015
42	Shun Hing Square	Shenzhen	298.1	384	1996
43	Cemindo Tower	Jakarta	295.6	304	2015
44	Milad Tower	Tehran	293	435	2008
45	Kingdom Center	Riyadh	290.4	302.3	2002
46	Baiyoke Tower II	Bangkok	290	304	1997
47	Brys Buzz	Greater Noida	290	300	2017
48	Abeno Harukas	Osaka	287.6	300	2014
49	Spring City 66	Kunming	285.7	349	2018
50	Eureka Tower	Melbourne	285	297.3	2006
51	Etihad Tower T2	Abu Dhabi	281.6	305.3	2011
52	Northeast Asia Trade Tower	Incheon	276.7	305	2011
53	Eiffel Tower	Paris	276	300	1889
54	Menara Kuala Lumpur	Kuala Lumpur	276	420.4	1996
55	Overseas Union Bank Center	Singapore	275.8	277.8	1986
56	Columbia Center	Seattle	275	284.4	1984
57	Landmark Tower	Yokohama	273	296.3	1993
58	Zifeng Tower at Greenland Center	Nanjing	271.8	450	2010
59	Central Radio & Television Tower	Beijing	270.5	386.5	1992
60	JP Morgan Chase Tower	Houston	268	305.4	1982
61	Stratosphere Tower	Las Vegas	266	350.2	1996
62	Leatop Plaza	Guangzhou	264.7	302.7	2012
63	Republic Plaza	Singapore	262.9	276.3	1996
64	Lotte Center Hanoi	Hanoi	262	272	2014
65	Torre Costanera	Santiago	261	300	2014
66	Sydney Tower	Sydney	260	305	1981
67	GE Building	New York City	256	259.1	1933
68	Tianjin Radio & TV Tower	Tianjin	253	415.1	1991
69	Osaka World Trade Center	Osaka	252.1	256	1995
70	Etihad Towers T1	Abu Dhabi	251.2	277.6	2011
71	Henan Province Radio & TV Tower	Zhengzhou	251	388	2011
72	Tokyo Tower	Tokyo	249.6	332.9	1958
73	Colombo Lotus Tower	Colombo	248	248	2015
74	Zhengzhou Greenland Plaza	Zhengzhou	244.7	280	2013
75	The Shard	London	244.3	306	2013

Canton Tower, Guangzhou, has the highest semi-Ferris Wheel in the world; On top of the tower at 451 meters, cars travel around the building on an inclined track

To ascend to the 72-floor (244-meter) open-air viewing gallery at The Shard, London, it will cost you $45.70, or approximately $0.20 per meter

The first observation deck in China was the Liaoning TV Tower, Shenyang, completed in 1984. Currently six of the top 10 tallest observation decks are in China

Myth-busting: The Incredible "Shrinking" Washington Monument

Dru Smith

Interviewee

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Dru Smith
Dr. Dru Smith first entered NGS in 1995 after receiving his PhD. in geodetic science from Ohio State University. From 1995 until 2000 he performed gravity and geoid research, resulting in the GEOID96, CARIB97, MEXICO97 and GEOID99 geoid models. In 2001 he spent a year working for the Executive Secretariat of the Interagency GPS Executive Board, helping shape government GPS policy. In 2001 he returned to NGS and focused his research on using the CORS network to model the ionosphere. He is a member of the Institute of Navigation, the American Geophysical Union, the International Association of Geodesy and has previously served on the Board of Directors for the American Association for Geodetic Surveying.

In February 2015, the Washington Monument "shrunk" almost 10 inches (248 millimeters), when the United States National Oceanographic and Atmospheric Administration (NOAA)'s National Geodetic Survey (NGS) used CTBUH height criteria to determine the true architectural height of the famous cenotaph. As part of a dialogue with CTBUH, NGS used precise instrumentation to determine that the height of the structure was 554 feet, 7 11/32 inches tall (169.046 meters) instead of 555 feet, 5 1/8 inches (169.294 meters) as previously recorded. When the data was released around the President's Day holiday, the report was widely circulated in the media. CTBUH Journal Editor Daniel Safarik interviewed Dru Smith, chief geodesist of the NGS, to investigate a little further into the specifics of the project.

First things first. Most of our members use math extensively and sophisticated software to design, construct, and operate tall buildings. But many probably don't know exactly what a geodesist does. Can you shed a little light?

Geodesists are scientists who work in the field of geodesy, which focuses on the determination of the size and shape of the earth, its gravity field, and the positions of points on the earth. As part of that work, we also incorporate geodynamics and geophysics, such as the wobble of the rotation pole or the drift of tectonic plates. At its core though, geodesy is a measurement science, and geodetic surveys such as the measurement of angles, distances, gravitational attraction, etc., have been the core of geodesy for centuries.

The Washington Monument recently underwent an extensive renovation. Why did the NGS undertake a remeasurement of the structure during this time?

The NGS has had a collaborative relationship with the National Park Service (NPS), the stewards of the Washington Monument (WM) and the National Mall area, for nearly a century. The most visible part of that collaboration has been geodetic leveling surveys to points around the base of the WM, which can detect differential height changes at the submillimeter level. The purpose has been to monitor whether any subsidence has occurred around the National Mall area.

However, two special surveys were done, one in 1934 and one in 1999, where NGS actually occupied the peak of the monument with survey instruments. This was possible because in both of those years, scaffolding surrounded the monument for renovations. In 1934, the survey was a triangulation survey (angles measured between distantly-sighted objects, such as church spires and flagpoles), which helped determine the latitude and longitude, of the peak. This was useful, as the Washington Monument peak is a reasonable point for surveyors to sight from the ground, but it had never before been directly occupied to determine its latitude and longitude. The 1999 survey was primarily a demonstration of the capability of GPS (the Global Positioning System) to accurately determine elevation (see Figure 1).

Having an accurate determination of the actual peak of the WM in latitude, longitude and elevation helps the NPS in its mission of maintaining the monument, since these determinations can be used to help detect tilts or sinking. As such, when NGS learned that the WM would again be encased in scaffolding (to repair damage from a 2011 earthquake) we sought, and obtained, NPS permission to occupy the peak again (see Figure 2). However, this time, our goal was to position the peak to millimeters, something that had not been done in the past. The reason was that we hoped to establish a baseline for future surveys, should they occur, to monitor any motion of the peak.

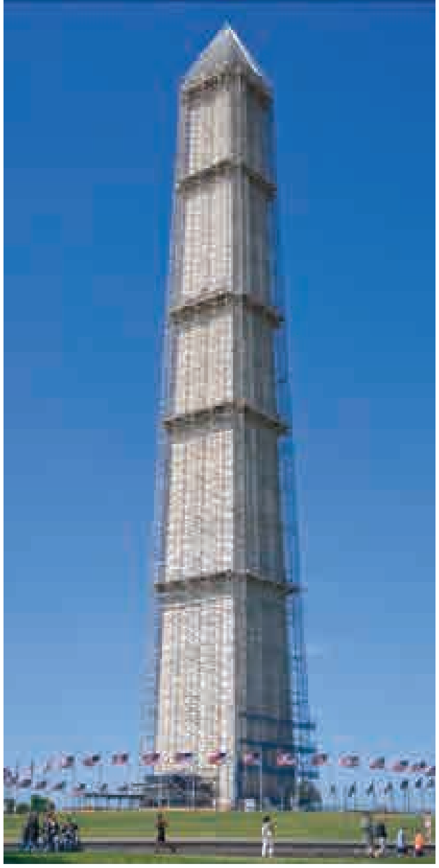

Figure 1. Washington Monument enclosed in scaffolding. © Ron Cogswell. Source: Wikimedia Commons

NGS did not set out to determine the architectural height of the monument itself, but as such a measurement had usefulness (in determining if any actual compression of the building occurs over the years), not to mention general public interest, it was deemed worthwhile to expend the additional effort to properly collect what was needed to add this measurement to the overall survey.

What kinds of equipment and methodology did you use for the latest measurement (I'm hoping the answer has the words "rappelling" and "lasers" in it)?

Figure 2. Height is measured from the level of the lowest, significant, open-air, pedestrian entrance to the architectural top of the structure (CTBUH criteria).

NGS was not involved in rappelling, but the NPS has some wonderful pictures of the initial damage assessment phase, where rappelling from the peak was done! Lasers played a small role – our collimators, devices that narrow and align particle beams, use lasers – but most of the electromagnetic work of our instruments is via microwaves.

There were three basic phases of the survey, each with its own equipment and purpose: Geodetic leveling, traverse, and GPS.

Geodetic leveling is a line-of-sight survey used to determine height differences from one point to another. The main equipment is a geodetic level and a pair of level rods. The process uses short, balanced sight lengths, back to one rod, then forward to another. This pattern continues, eventually connecting two points of interest. Using this method, two types of heights were determined at all points in and around the monument: North American Vetical Datum (NAVD) 88 "orthometric" heights (which are the official elevations used in all Federal geospatial products) and "architectural heights" (determined by adopting the CTBUH recommendation for where "zero architectural height'" should be) (see Figure 3).

Traverse uses a Total Station and Reflectors. A Total Station looks like a traditional survey instrument with a scope, but unlike historic instruments which could only measure horizontal angles and vertical angles, a Total Station can also electronically measure slope distances to a reflector as well (see Figure 4). The traverse survey measured angles and distances between about 10 different points around the monument. Using this data, we were able to transfer both orthometric and architectural heights to the peak, as well as determine its latitude and longitude.

How did GPS play a role?

GPS was used in this survey, but with some difficulty (which we had also experienced in 1999). A GPS survey consists of a "geodetic-quality" GPS receiver (much more expensive and accurate than the one in your smartphone) to position points to a few centimeters. In our

Figure 3. The view of the top of the Monument as viewed through the Total Station surveying tool.

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About the Council

The Council on Tall Buildings and Urban Habitat is the world's leading resource for professionals focused on the inception, design, construction, and operation of tall buildings and future cities. A not-for-profit organization, founded in 1969 and based at the Illinois Institute of Technology, Chicago, CTBUH has an Asia office at Tongji University, Shanghai, and a research office at Iuav University, Venice, Italy. CTBUH facilitates the exchange of the latest knowledge available on tall buildings around the world through publications, research, events, working groups, web resources, and its extensive network of international representatives. The Council's research department is spearheading the investigation of the next generation of tall buildings by aiding original research on sustainability and key development issues. The Council's free database on tall buildings, The Skyscraper Center, is updated daily with detailed information, images, data, and news. The CTBUH also developed the international standards for measuring tall building height and is recognized as the arbiter for bestowing such designations as "The World's Tallest Building."

Council on Tall Buildings and Urban Habitat

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