On the 50th anniversary of the Council on Tall Buildings and Urban Habitat's founding, the CTBUH 10th World Congress occurred in Chicago, Toronto and New York City from 28 October to 2 November 2019. Focusing on the theme "50 Forward | 50 Back: The Recent History and Essential Future of Sustainable Cities," the Congress explored the most significant advancements in tall buildings and cities from the last 50 years, whilst inquiring into the future of our cities 50 years from now. This collection of papers, which were originally presented at the 2019 World Congress, represents a critical reflection on both the skyscraper typology and urban development as a whole, by marking their trajectory to date, and considering the evolutions that must take place to accommodate a dynamic and uncertain global future.

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Congress Proceedings
A collection of state-of-the-art, multi-disciplinary papers on urban design, sustainable cities, tall buildings, and technologies.

Editors: Jason Gabel & Daniel Safarik

The Recent History and Essential Future of Sustainable Cities
The Council on Tall Buildings and Urban Habitat (CTBUH) is the world’s leading resource for professionals focused on the inception, design, construction, and operation of tall buildings and future cities. Founded in 1969 and headquartered at Chicago’s historic Monroe Building, the CTBUH is a not-for-profit organization with an Asia Headquarters office at Tongji University, Shanghai; a Research Office at Iuav University, Venice, Italy; and a Research & Academic Office at the Illinois Institute of Technology Chicago. 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.”

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Introduction

On the 50th anniversary of the Council on Tall Buildings and Urban Habitat’s founding, the CTBUH 10th World Congress returns to the Council’s home: Chicago. Focusing on the theme 50 Forward | 50 Back, the Congress explores the most significant advancements in tall buildings and cities from the last 50 years, whilst inquiring into the future of our cities 50 years from now. This event thus represents a critical reflection on both the skyscraper typology and urban development as a whole, by marking their trajectory to date, and considering the evolutions that must take place to accommodate a dynamic and uncertain global future.

Fifty years ago, in 1969, plans were put forth to build the Sears Tower in Chicago, a 442-meter skyscraper that would take the title of “World’s Tallest Building” when it completed five years later. That same year, the New York City Planning Commission released the Plan for New York City, a six-volume tome that sought to refocus attention on neighborhood-level improvements, as a way to soften and humanize the ill effects of numerous urban-renewal schemes that had decimated cities for the previous two decades. The tension between human-centric and technologically-advanced design progress was brought into sharp focus at this time—but, arguably, has never truly been resolved.

Since that time, cities have grown exponentially, all incorporating—in some way—the lessons and technologies of those that came before them. Whereas only 37 percent (1.3 billion) of the global human population lived in urban areas in 1969, today that figure has increased to 55 percent (4.2 billion), with further urban growth projected at 68 percent (6.7 billion) by 2050. Close to 90 percent of this growth will take place in Asia and Africa. But not all urban areas are destined for unabated growth. Those vulnerable to natural disasters or severe economic instability may see major population losses, as residents seek out locations with fewer crises and improved education, employment opportunities, health services, and housing.

On a building scale, the manifestation of the contemporary skyscraper is a collective accomplishment—one that has experienced several wholesale evolutions over time. Whereas back in 1969, at the formation of the CTBUH, the tall building was predominantly a technical challenge, now it is, arguably, more of a social challenge—how does it fit in with, and enhance, society? With the technological barriers towards height now largely addressed, an emphasis is being placed on making more humane, smarter, greener, more efficient skyscrapers that are better integrated with their cities, and better stewards of the urban environment. But much still needs to be done.

We thus stand at a critical juncture in time, amidst major change in the typological status of tall buildings, the cities they call home, and the people that inhabit them. The 10th World Congress, Chicago, directly addresses critical issues in the future progression of our cities, drawing the most important lessons from the past. All relevant issues—including urban planning and infrastructure; smart technology/automation; resilience and climate change; passive environmental...
strategies; tall timber structural systems; modular construction; inter-/intra-building transportation; the future of the workplace; building modeling; and many others—will be explored.

Why Chicago

With the longest history of any modern city in building skyscrapers, Chicago is perfectly positioned to contemplate the integration of tall buildings into our urban fabric—from both a technical standpoint and a socially responsible one. Chicago was a hotbed of skyscraper innovation in the 1880s, resulting in advances in many building technologies, from skeleton framing to foundations. In 1974, the Sears (now Willis) Tower took the title of World’s Tallest Building—and held it for nearly a quarter of a century. With a world-famous skyline that contains buildings like the John Hancock (now 875 N. Michigan) and the Aon Center, and an eponymous architectural style that emphasizes height through vertical lines, Chicago’s architectural signature is unique. Furthermore, the United States’ third largest city borders the country’s third largest freshwater lake—the massive Lake Michigan—granting Chicago the potential to lead urban environmental stewardship policies as climate change threatens resource access.

When the Council on Tall Buildings and Urban Habitat relocated from its former headquarters in Bethlehem, Pennsylvania to Chicago in 2004, it was with the knowledge that the Windy City’s capacity to push architectural boundaries was what percolated the skyscraper typology over 100 years prior. It is with this same awareness that the CTBUH chose its home city for the 2019 World Congress, 50 Forward | 50 Back in celebration of its 50th anniversary, through a conference that examines the past to inform riveting visions for sustainable cities of the future.

About this Book

This Proceedings represents a curated capture of ideas presented at the CTBUH 10th World Congress, which took place in Chicago from 28 October to 2 November 2019. In this volume you will find critical reflections on the past, present, and future of tall buildings and urban habitats around the world, kicking off with a data study that quantifies the proliferation of tall buildings over the past 50 years, while illustrating the evolution of distinct architectural styles that took place during that time for the typology.

A collection of three papers then presents the results of an open feedback campaign seeking to capture the most influential tall buildings and urban interventions from the past half-century and expound upon the most highly anticipated innovations and technologies that have the potential to change cities forever. These pieces give way to a collection of research papers organized under the Congress themes of 50 Back, The Now, and 50 Forward that relate to presentations given on-site at the event. The discussion embraces every discipline, from urban planning to structural engineering, architectural design to vertical transportation, fire safety considerations to technological solutions.

Equal parts retrospective, contemporary, and future-forward, this volume expresses the aspirations and direction of an industry that seeks to accommodate the complexities of an ever-changing world. We hope you enjoy reading, and that the contents herein inspire even greater levels of innovation in your work, no matter the subject.

1: The Skyscraper Center, CTBUH
3: 2018 Revision of World Urbanization Prospects, United Nations
4: The Council holds at least one conference per year and a world congress every five years in an active tall building city around the world. Larger in scale than the annual conferences, world congresses are substantiated by paper-based proceedings and encapsulate a geographic audit of the best developments happening in each region around the world.
Chapter 1

INDUSTRY REFLECTIONS
As part of the 10th CTBUH World Congress, the CTBUH network was approached with the question: "Which tall buildings completed in the last 50 years have profoundly enhanced the cities in which they are located and/or have greatly influenced the practice of designing tall buildings?" The request was to nominate a "50 BACK: Influential Tall Building" and describe why the building should be recognized, summarizing the contributions that it has made to society or the industry at large.
The skyscraper has a history extending back more than 120 years, but it entered a new phase of innovation and acceleration in the late 1960s. The Council on Tall Buildings and Urban Habitat was founded in 1969 to embrace and interpret the rapid changes taking place in the field of high-rise design and engineering. Throughout its history, CTBUH has highlighted best practice examples of tall buildings that represented a significant change in thinking or technique, by means of Journal case studies, conference proceedings, and since 2002, the annual Awards program.

The tall buildings captured in this feature are selected on the same criteria, through the combined input of the CTBUH Data Research & Insights team, CTBUH Leaders, and a call to the member constituency at large. Each represents a milestone in the development of the typology, tracking the development of the tall building from a predominantly commercial office tower with repetitive floor plates, to a “vertical city” with the mix of uses, variation in façade materials, and variety of interior and exterior spaces implied by the title. Across these examples, we see the arrival and departure of the distinct International and Post-Modern styles, as well as the overlapping parametricism and contextualism that dominates the contemporary scene. We see the transition from symbols of North American corporate power to broadcasting devices for arrival of entire cities and countries on the global stage. The importance of environmental sustainability takes on as important a role as cultural and economic longevity. And, as some of these skyscrapers hit the half-century mark, we see them aging gracefully, into new functions, sometimes radically changing appearance and even height. From this, we learn that the development of the skyscraper typology is not a simple case of linear hand-offs from one generation to the next; rather, it is an interpolating dialogue that will continue to inform and inspire us for the next five years and beyond.

The full spectrum of 50 influential tall buildings constructed over the past 50 years is on view in the skyline graphic (see pages 30–31). Highlighted buildings receive short profiles on the following pages, exemplifying critical milestones in the half-century dialogue between iconicity, contextualism, environmental consciousness and structural innovation.

875 North Michigan Avenue (formerly John Hancock Center), Chicago, 1969

The John Hancock Center employed the first braced-tube structural system for a high-rise building. It accommodates residential, commercial, and office spaces where people can live and work, and exhibits the scale and grandeur of a robust tower of strength with honest visual expression, without embellishment. It introduced a new, recognizable vocabulary of structural expression of tall buildings that continues today, with variations like the diagrid system. The exterior bracing allowed 875 North Michigan to consume the same amount of steel as that of a conventional building half its height.

With the distinct expression of its façade, architecture and structure are one and the same. The tower represents the high point of the International Style soon followed by the Sears Tower. The building represents the result of collaboration

---

1: The submissions ultimately accepted for publication were sent by: Rod Abid, CTBUH Skyscraper Center Editorial Board, Bangkok; Mir M. Ali, University of Illinois at Urbana-Champaign, Urbana; Bridget Barnes, Skidmore, Owings & Merrill LLP, Chicago; Ana Bassat, b720 Arquitectura SL, Barcelona; Roland Beckmann, Werner Sobek AG, Stuttgart; Craig Blanchet, LeMansurer, Boston; Terri Meyer Boake, University of Waterloo, Toronto; Andrea Giachetti, University of Florence, Florence; Richard Hening, LeMansurer, Boston; Tailung Hung, Siemens, Hong Kong; Richard Lee, C.F. Lee & Partners Architects/Planners, Taipei; Lucy Moloney, PTW Architects, Sydney; Christos Papas, Zaha Hadid Architects, London; Jonathan Schiffman, Skidmore, Owings & Merrill LLP, New York; Mohammed Sharif, JNTUH, Hyderabad; Hassan Siraj, Burjeel Engineering Consultancy, Abu Dhabi; Clare Swan, Ethos Urban, Sydney; Iping Yang, Taipei Financial Center Corp., Taipei
Chapter 2

50 BACK
Lift and the City: How Elevators Reshaped Cities

Markus Jetter
Head of Research & Innovation Center Rottweil
thyssenkrupp
Rottweil, Germany

With a degree in Electrical Engineering, Markus Jetter has been working in the elevator industry since 1991 for thyssenkrupp Elevator AG, holding various positions in the areas of contract design, product development, high-rise projects, consulting and research. Since 2013 he has been concentrating on ropeless elevator systems. His latest research activities include a wide range of elevator innovations in the transformation process of digitization, energy management, performance and process optimization over the product lifetime.

Abstract

We are now living through the most dramatic change in the human history, as far as population and urbanization is concerned. In 1969, the rural population accounted for about 70 percent of the global population. By 2069, urban population will account for more than the same percentage. With half of the world’s population already living in cities, we are in the midst of the most significant demographic shift in modern history. The rising density of urban areas requires the development of more mid-to-high-rise buildings, which allow for the most environmentally friendly and cost-effective usage of space. Tall buildings are becoming more like vertical cities, providing office, residential and commercial space. Just like any other place in a city, every location within a building needs to be well connected if it is to attract commercial investors, tenants, and shoppers. To achieve this level of connectivity, buildings need future, flexible transport systems, similar to a metro.

Keywords: Digital Twin, Energy Management, Robotics, Ropeless Elevator, Skybridges, Urban Mobility

Introduction

The dramatic changes that will characterize the near-term development of future cities require quantum leap in the technology used to transport passengers and goods, to achieve the highest possible performance in buildings, where space is at a premium.

The elevator enabled the skyscraper and its dynamic development over the last century, but at the same time, this technology is limiting further progress in height and shape today. With the reinvention of the elevator and the full integration into the digitized building, the next incremental—and radical—steps in the story of lifts in the city are at hand, changing the shape of cities once again.

Multiple Cabins Per Shaft

A first major step beyond the traditional single cabin in a single shaft was the introduction of a second, independent car operating in the same shaft (Thumm 2004). One such system, TWIN (see Figure 1), features two cars operating independently in one shaft, making efficient use of available space while transporting up to 40 percent more passengers than conventional elevators. Each TWIN elevator has its own major mechanical and electrical components, but shares the same guide rails and landing doors with other cabins in a single elevator shaft. By reducing the number of necessary shafts, additional floor space is given back to the building, creating additional leasing opportunities. The Coda building in Atlanta, for example, features 10 TWIN elevators in five shafts.

Worldwide, there are more than 50 buildings with approximately 200 TWIN elevators installed, with many more are expected to follow. Further installations are planned at Hekla Tower in Paris’ La Défense district, Sunshine Insurance Group’s new headquarters in Beijing, as well as in two new towers in the financial district of Chengdu.

Although multi-cabin/single-shaft technology is well established in the market, another step was needed in order to keep pace with the multidimensional scope of urban development.
Ropeless Elevator Systems

The long-awaited ropeless elevator system affords the freedom to use a variable number of cabs in the same shaft, and to move the cabs not only vertically, but also horizontally within a fully flexible matrix of transportation routes through a building (Jetter & Gerstenmeyer 2015).

MULTI (see Figure 2) has the potential to truly revolutionize building design, offering total freedom to architects and building developers to create the best places to live and work, while improving the business case for multilayered, city-scale tall building developments. For many decades, architects and planners have envisioned vertical cities (King 2016), but these concepts will be much closer to feasibility with the introduction of the next generation of vertical and multidirectional transportation systems.

A ropeless elevator system that allows cabs to travel with narrow clearances and to change directions (see Figure 3) brings the monopoly of the conventional roped elevator to an end—160 years after its introduction. Linear motor technology allows cabins for the first time to travel vertically and horizontally in a building.

Numerous projects worldwide are planned to incorporate such a revolutionary system. The MULTI system is on its way to market and is being finalized in a new test tower in Rottweil, Germany (Jetter 2018) (see Figure 4).

In order to support architects, building planners and consultants introduce this new technology, a joint research project between the CTBUH and thyssenkrupp Elevator AG was performed to elaborate the potential for multidirectional transportation in tall buildings. The resulting report (Belmonte, Trabucco & Schöllkopf 2019) (see Figure 5) starts with an impressive historical overview of elevators and how they...
World’s Biggest (Tall) Buildings

Abstract

In both professional circles and in the public eye, the subject of the World’s Tallest Building (WTB) has held the spotlight for more than a century. After the title of WTB left US shores at the end of the 20th century, competition and press attention went global. Key points of discussion have been how to measure height and what parts of the building to count. Yet there is another competitive category of high-rise size that has been ignored: Biggest. What were, and are now, the World’s Largest Buildings (WLB) measured by floor area? Area, after all, is the dimension that owners value most. Measured by floor area, the American skyscrapers completed in the 1970s—the original World Trade Center and Chicago’s Sears (now Willis) Tower—were the biggest ever constructed (and they may still hold that title when rigorous analysis is attempted). Twenty-first century supertalls, especially in the Middle East and in China, have far surpassed the former giants in height—but not in floor area. One part of the evolution of the skyscraper is the story of ascending height. Another is of increasing size—but only to a point. Notably, the apogee of that evolution came 50 years ago.

Keywords: Gross Floor Area, Height, World’s Biggest Buildings, World’s Largest Buildings

Introduction

What is the world’s tallest building and why do we care? This perennially popular subject has held the spotlight for more than a century. Woolworth, Empire State, World Trade Center, and Sears Tower: these American giants capture the imagination and have inspired numerous books, TV shows, and podcasts. Some stories about the forces that drive the ambition for height have been told so often that it seems they must be true—for example the supposed “race into the skies” of the former partners, then rival architects of the Chrysler Building and 40 Wall Street, William van Alen and Craig Severance. But good stories can often create false narratives.

Clearly, the title of World’s Tallest Building (WTB) carries bragging rights, and that celebrity does translate into value. Add the competition between countries or continents (as began in 1996) and you have forces at work bigger than egos. The subject is catnip to the media, especially as a new tower ascends and a record will be broken, attracting free worldwide attention. It also continues to pay off for years or decades in the many “Tallest” charts and documentaries that are evergreens on The History Channel and the like. These buildings get ratings!

Perhaps it’s human nature to fixate on “tallest.” But arguably, the primary focus on vertical height is a failing from a professional perspective—whether the profession of historian or of organizations such as CTBUH. Is this too pedantic? What does it hurt if TV shows repeat stories about the rivalry of architects William van Alen and Craig Severance who, supposedly, ratcheted up the height of their towers’ tips to best a former partner who was now a competitor? Well, first, that story suggests to the general audience that it’s architects who decide how tall a building will be. Or that you can just add tons of superstructure to an already-constructed tower without re-engineering the design below. CTBUH has expended considerable energy on the topic of “Tallest,” including distinguishing heights based on the tip, architectural top, or highest occupiable floor. We need to find a way to move beyond the storyline of vertical height in excelsis.
So let’s turn our attention to another superlative category: World’s Biggest Buildings. What were, and are now, the World’s Biggest (Tall) Buildings measured by floor area? There are no charts on the CTBUH website of this category. An inattention to floor area makes no sense—area is, after all, the dimension that owners of skyscrapers value most. Square meters or feet generate rent. Admittedly, tracking and comparing buildings by area is hard to do, especially if one wants to be accurate and consistent. Formulas for calculating Gross Floor Area (GFA) can vary widely across cities, countries, and decades—indeed, up to 24 percent, as an excellent CTBUH research paper has calculated. When the Starrett Brothers and Eken built the Empire State Building, they said it was 2.1 million square feet: today the building management’s fact sheet calls it “2.7 million square feet of office space,” while the Skyscraper Center database lists the Tower GFA as 2,248,355 square feet. We should all be grateful that CTBUH has been adding the Tower GFA on the information page of new buildings. Alas, though, this information is simply posted as received from the developer, so it reflects whatever formula is used in that city or region.

The Skyscraper Museum used these GFA statistics to create some graphics to simultaneously visualize both the height and the area of some of the world’s biggest buildings (see Figure 1). What can we learn from this chart? Certainly, we see that Tall and Big are very different things. Which skyscraper today has the greatest GFA? It’s not a simple answer. It may be the complex of Abraj Al Bait in Mecca with its centerpiece, the 601-meter Makkah Clock Tower, which, conjoined with the

![Figure 1. World’s biggest buildings by heights and area. © The Skyscraper Museum](image-url)
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On the 50th anniversary of the Council on Tall Buildings and Urban Habitat’s founding, the CTBUH 10th World Congress occurred in Chicago, Toronto and New York City from 28 October to 2 November 2019. Focusing on the theme 50 Forward | 50 Back: The Recent History and Essential Future of Sustainable Cities, the Congress explored the most significant advancements in tall buildings and cities from the last 50 years, whilst inquiring into the future of our cities 50 years from now. This collection of papers, which were originally presented at the 2019 World Congress, represents a critical reflection on both the skyscraper typology and urban development as a whole, by marking their trajectory to date, and considering the evolutions that must take place to accommodate a dynamic and uncertain global future.

Whereas back in 1969, the tall building was predominantly a technical challenge, now it is, arguably, more of a social challenge—how does it fit in with, and enhance, society? With the technological barriers towards height now largely addressed, an emphasis is being placed on making more humane, smarter, greener, more efficient skyscrapers that are better integrated with their cities, and better stewards of the urban environment. We thus stand at a critical juncture in time, where, amidst rapid densification, cities and tall buildings must deliver a greater quality of life to the people that inhabit them.