Council on Tall Buildings and Urban Habitat

The Future of Tall

A Selection of Written Works on Current Skyscraper Innovations

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Front Cover: MahaNakhon Tower, Bangkok. Source: Pace Development

Back Cover (Top to Bottom): International Commerce Centre, source: Sun Hung Kai Properties; MahaNakhon Tower, Bangkok, source: Pace Development; TopDownWay, source: Despe Spa; Delano Hotel, Miami, source: Ian Schrager Company; MahaNakhon Tower, Bangkok, source: Pace Development; Asakusa Culture Tourist Information Center, Tokyo, source: Takeshi YAMAGISHI

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Introduction

Imagine a world where skyscrapers operate autonomously, where your presence is detected upon entry and button-less elevators whisk you away to your destination automatically. Imagine a world where our buildings constantly record environmental data through an expansive network of sensors in a proverbial "internet of things" – data that is used to optimize thermal comfort, air quality, lighting, security systems, and evacuation strategies. Imagine the construction of these buildings taking months, not years, due to large components being prebuilt in dedicated factories. These innovations might seem to come straight out of a science fiction novel, but in truth, these advancements are well into their development, with many already employed in skyscrapers around the world. The future is upon us, and with it has come ideas that promise to reshape the ways we interact with cities on both horizontal and vertical planes. As if this wasn't enough, new forms of quantification and research are allowing us to glimpse the ramifications of the decisions we make in the design and engineering process, increasing the likelihood that the buildings that are built today will be sustainable, economical, and lasting.

The idea of a "smart skyscraper" isn't anything new. Futurists and visionaries have long pondered the outcome of combining the most extreme forms of architectural practice with the latest in digital technology. With the growing ubiquity of technology in our daily lives and the still-rapid increases in the computational power of integrated circuits, we find that the daydreams of the past weren't far off from what is now within our grasp. Sophisticated networking systems have opened the door to high-performance buildings that use an array of sensors to aggregate diverse sets of data over time. This data can then be used to optimize performance, predict future patterns of behavior by occupants, and form strategies for yet-unseen scenarios. In New York City, for example, a number of buildings have been outfitted with Di-BOSS, a building operating system that uses data analytics and machine learning to guide building operators toward optimal performance in real time. Additionally, on the other side of the world in Hong Kong, the International Commerce Centre has been using a combination of integrated technology and operational systems to make the building one of the highest performing skyscrapers in the world.

As with the skyscrapers of old, vertical transportation systems remain a critical component of increasing a building's performance. The smooth flow of people throughout a tall building is critical for tenant satisfaction and life safety. As buildings get taller and accommodate more people, the likelihood of rush periods for elevators continues to grow. Luckily, several innovations have been devised to ameliorate these issues. One such invention, Schindler's PORT system, uses multiple methods of identity verification to confirm the presence of registered building occupants, preprogramming the destinations of each elevator in the building and telling users which cab to use via their smartphones. Not only does this system optimize vertical travel, but also adds several layers of security to the elevator system. There are also advancements that – although currently in the R&D stages – could completely change the way tall buildings are designed. Thyssenkrupp's MULTI is a vertical transportation system that relies on magnetic levitation instead of conventional hoist ropes, drastically minimizing the area required for elevator systems and providing the ability to transition from vertical to horizontal travel, a feat that would allow for entirely new vertical typologies.

The construction of tall buildings is also advancing quickly, with a host of modular methodologies that – if properly optimized – could drastically shorten project timelines and introduce new efficiencies to on-site working crews. But the potential of modular building goes well beyond the construction site, in fact, it may be critical in order to meet global housing demands, which are expected to spike in the years leading up to 2050. The limiting factors of this technology are two-fold: first, the transportability of modules must be addressed so that they are small enough to travel by truck unimpeded, but large enough to realize significant construction efficiencies; second, modules must be fabricated at a pace that keeps up with the cranes' ability to install modules on-site, thereby creating a continuous construction flow. With a number of companies around the globe addressing these issues, it is likely only a matter of time before skyscrapers rise faster than ever before.

But what of the buildings that already exist? With many tall buildings reaching

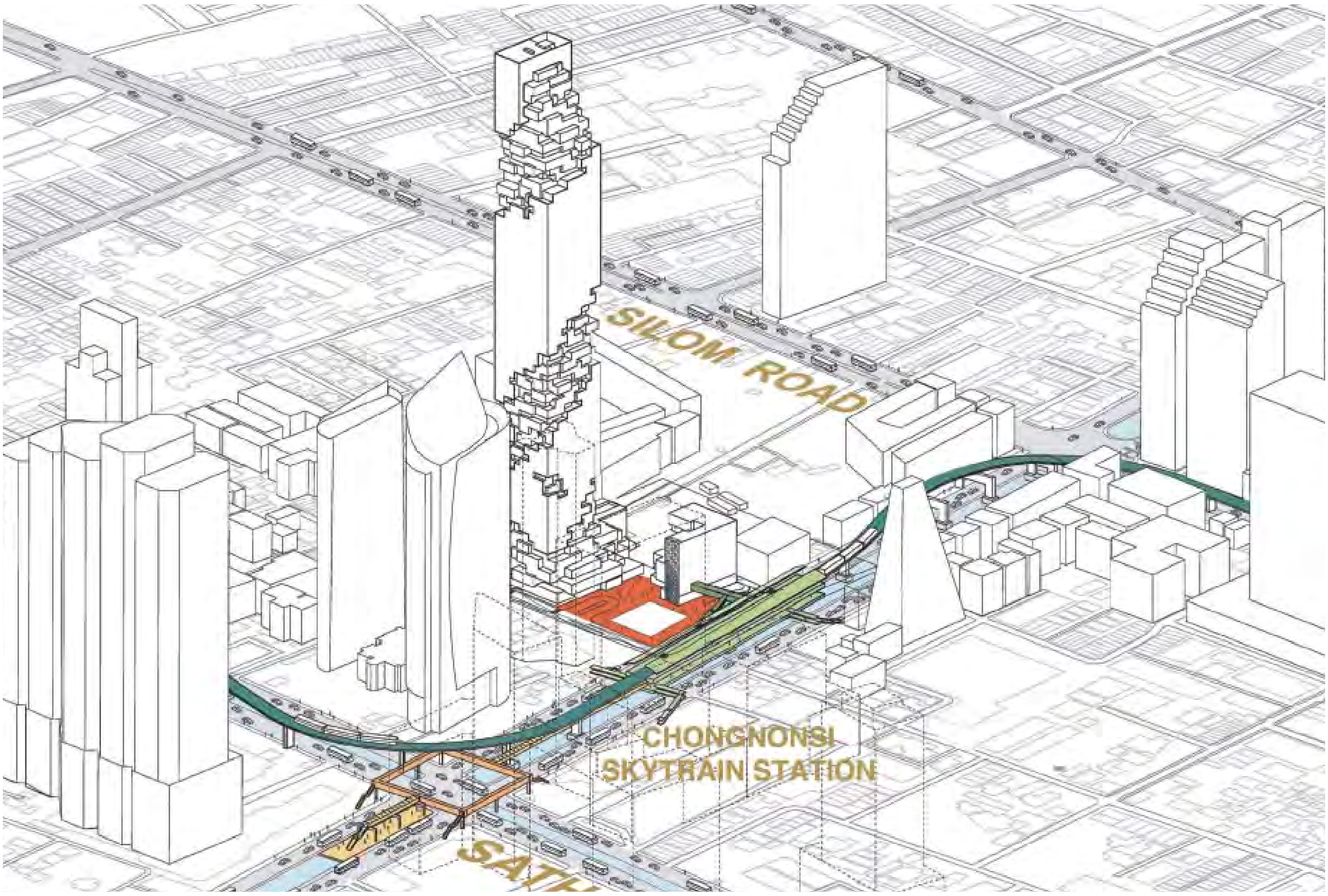
MahaNakhon: A Pixelated Punctuation Mark on the Bangkok Skyline

Sorapoj Techakraisri, CEO, *PACE Development*

As Thailand becomes an increasingly important economic force in Asia, the quality of its architecture has risen to match the expectations of an increasingly sophisticated clientele. MahaNakhon, a 314-meter, mixed-use tower, will be the tallest building in the country when complete in 2016 and command its highest residential prices. The international design and development team has created a development that is optimized for the tropical climate of Bangkok, and introduces a level of international design quality previously unseen in the capital. Its "pixelated" design concept affords highly valuable outdoor space to tenants, while breaking down the mass so as to better integrate with the urban fabric. Importantly, the development also addresses the city's notoriously congested traffic conditions and its lack of open spaces by connecting directly to the Skytrain rapid transit system, and by using its design to return part of the property to public use.

MahaNakhon is a mixed-use development in Bangkok, including Ritz Carlton-branded serviced residences, a hotel, retail, an observation deck, and an outdoor bar. Meaning "Great Metropolis" in Thai, MahaNakhon will be 314 meters high, earning its place as the tallest building in Thailand when completed at the end of 2015. Designed for the warm climate of Thailand and located in the prime Sathorn/Silom CBD area, the building's unique "pixelated" form creates a series of large-scale outdoor areas, perfect for tropical climates, offering indoor/outdoor dining, residences, and retail layouts that are refreshingly diverse. The building was envisaged as a representation of the development of Bangkok, breaking away from the traditional podium-and-tower configuration, instead producing a much more organic form rising above its neighbors, one which melts into the ground and the street life for which Bangkok is well-known.

The aim of the development was to provide three independently financially successful elements, in a 1+1+1=5 configuration, enabling each component to feed into and reinforce the other. The three elements are residential (The Ritz-Carlton Residences, Bangkok); hotel (The Edition Hotel, operated by The Ritz-Carlton); and, retail (the MahaNakhon CUBE, Sky Observation Deck,



Opposite: The 314-meter MahaNakhon building in its context, the Sathorn district of Bangkok. Source: PACE Development

Top: Axonometric view of MahaNakhon's location near the Bangkok Skytrain and other high-rises in the Sathorn district. Source: PACE Development

Project Data: MahaNakhon Tower

Location: Bangkok, Thailand
Height:
- **Architectural:** 314 meters (1,031 feet)
- **To Tip:** 314 meters (1,031 feet)
- **To Occupied Floor:** 299 meters (981 feet)

Floors Above Ground: 75
Floors Below Ground: 1
Tower Area: 150,000 m^2 (1,614,587 ft^2)
Use: Residential / Hotel
Structural Material: Concrete

Proposed: 2009
Start of Construction: 2011
Completion Date: 2016 (expected)

Number of Apartments: 207
Number of Hotel Rooms: 159

Owner/Developer: PACE Development Corporation Plc.
Architect: Office for Metropolitan Architecture; designer & partner-in-charge Ole Scheeren (now at Buro Ole Scheeren)
Structural Engineer: Bouygues Thai Ltd; Warnes Associates Company Limited (design); CivilPark International, Robert Bird Group (peer review)
MEP Engineer: P & T Group (design)
Main Contractor: Bouygues Thai Ltd
Other Consultants: CivilPark International (geotechnical); David Collins Studio, Ian Schrager Company, Kengo Kuma and Associates (interiors)

Regional Materiality in the Asian Context

Kengo Kuma, Partner, *Kengo Kuma and Associates*

As the lead interior design architect in collaboration with Ian Schrager on the EDITION Hotel in the MahaNakhon, Kengo Kuma and Associates employed their extensive Asian design experience to inform the hotel's unique public interiors and guest rooms. Since each EDITION Hotel is expressive of its cultural context, it was critical to engage an architect that had a deep understanding of local design imperatives, and Kengo Kuma's commitment to regional materiality proved particularly applicable to the philosophy of this new hotel brand. Mr. Kuma's experiences throughout the Tohoku and Shikoku regions of Japan in the 1990s had a great impact on his architectural work and forever changed his outlook on the connection between place, relationships, and the built environment.

History is Directed by Disasters – Why We Should Examine Our Own Ground

What I am most interested in now is inverting the structure of a culture that is centered on the city. The 20th century was an age of industry and an age in which everything from material goods, information, and culture flowed from metropolises to local towns and villages.

Following the same vector, architecture too flowed from the center to the periphery. Concrete, steel, and glass produced in metropolises were transported to localities, and buildings throughout the world came to be constructed of the same materials with the same details. Trends in design too flowed outward from metropolises. The flow of information in the 20th century followed a familiar pattern: trends that emerged in New York, London, or Paris were transmitted to Tokyo and reached local towns and villages in Japan several years or decades later.

The end result was the destruction not only of local culture but of all local life. Local buildings were once constructed of locally produced wood, stone, clay, and paper, but such materials fell into disuse. Craftsmen skilled in the use of such materials lost their livelihoods and disappeared, and no one was there to follow in their footsteps. Local economies and lives as well as local cultures were destroyed through this process.

I am convinced that the earthquake and tsunami that struck the Tohoku region of Japan on March 11, 2011 provided an

Left: Regional map of Tohoku, Japan. (cc-by-sa) TUBS

Opposite: Aerial view of the damage caused by the 2011 earthquake in Tohoku. (cc-by-sa) BotMultichillT

opportunity to invert this 20th-century social and cultural structure. That is because the Tohoku region is the area with the richest natural environment in Japan and the place where many craftsmen with skills that utilize that natural environment lived and worked. However, the Tohoku we saw destroyed by the earthquake and tsunami was not the old Tohoku with which we were familiar. It was not the Tohoku with the rich natural environment, the Tohoku that had been a paradise of craftsmen. Row after row of prefabricated housing units had been assembled from parts prepared in factories, and the people of Tohoku living in those units commuted to work in cities by car. A lifestyle similar to that of American suburbanites had destroyed the rich and distinctive culture of the Tohoku region. When I saw the tsunami washing away those American-style houses and cars, Noah's Flood came to mind. God sent the biblical Flood to punish an arrogant, corrupt humanity. The earthquake and tsunami seemed to me an expression of the anger of the gods at the way all of us had forgotten or ignored the fearsome power of nature. In that sense the tsunami was much like Noah's Flood.

The Tohoku region is a special place for me personally. I opened my office in 1986, but the bursting of the economic bubble in 1992 began a decade of recession in Japan. During those ten years, I received no commissions in Tokyo. My office managed to survive by doing small, local projects.

I was helped out during those ten years by jobs in the Tohoku and Shikoku regions. Those are the most underdeveloped and impoverished regions in Japan. One reason for this is their distance from Tokyo, but another has to do with topography. Steep mountains rise all the way to the coastline in both Tohoku and Shikoku; as a result, large plains do not exist, and areas are cut off from one another. Both Tohoku and Shikoku are essentially collections of countless small valleys.

This topography hindered the dissemination of a central culture transmitted from Tokyo. Because of this topography, both Tohoku and Shikoku lagged behind other regions with respect to 20th-century trends. Conversely, it was thanks to this topography – those valleys – that both Tohoku and Shikoku retained the rich cultural characteristic of small places. The richness and strength of that culture cannot be understood until one has worked together with the people who live there – until one has made things, eaten local food, drank local sake, and talked together with local craftsmen. In the decade after the bubble burst, I had an opportunity to learn from Tohoku and Shikoku the richness of small places. I probably would not have been able to change had I not had those ten years of experience. I probably would not be designing the kind of buildings I am designing now. That is why I continually tell students that a recession is the best of times for an architect and that having no jobs is the most fortunate thing that can happen to an architect. One tends to repeat one's past; one rarely attempts to change. One does not try to learn from the changed circumstances of a new era.

The biggest thing I learned from Tohoku and Shikoku was that relationships are what make a place rich. A place is not rich simply because it has a beautiful natural environment. A place is not rich simply because it is blessed with natural resources such as wood or stone, or because many skilled craftsmen live there. The relationships that tie these things together

A Whole Life Cycle Assessment of the Sustainable Aspects of Structural Systems in Tall Buildings

Dario Trabucco, Research Manager, *Council on Tall Buildings and Urban Habitat/Iuav University of Venice;* **Antony Wood,** Executive Director, *Council on Tall Buildings and Urban Habitat;* **Olivier Vassart,** R&D Director & **Nicoletta Popa,** Senior Research Engineer, *ArcelorMittal*

During a dedicated two-year-long research effort, the CTBUH analyzed all life phases of a tall building's structural system: the extraction and production of its materials, transportation to the site, construction operations, final demolition of the building, and the end-of-life of the materials. The impact of the building structure during the operational phase (i.e., impact on daily energy consumption, maintenance, and suitability to changes) was also investigated, but no significant impacts were identified during this phase.

Introduction

Goal Definition of This Study

The intended application of this study is to inform the community of professionals and researchers specializing in tall buildings on the environmental performance of the most common structural systems by providing the most accurate, up-to-date analysis on two key impact categories: Global Warming Potential (GWP) and Embodied Energy (EE). The limitations of this study are represented by the fact that only two impact categories (GWP and EE) are considered here, while other impact categories may lead to different results. Similarly, the obtained results are influenced by the quality of the information used, both in terms of environmental data (i.e., the "quality" and representativeness of the environmental data contained in the international databases used in the study) and data completeness (for example, environmental data on the end-of life of tall buildings simply doesn't exist, and had to be collected specifically for this research). The studied scenarios are representative of the most common structural systems for buildings of this height.

The main reason to conduct this study is that there is a lack of reliable and comprehensive information on the relevance of the construction phase for the environmental sustainability of tall buildings, and a comparison on the relative importance of selecting various structural materials and structural systems for a tall building is needed. The intended audience of this public study is the community of tall building experts involved in the ownership, development, design, planning, construction, operation, maintenance, and research of tall buildings. The study was commissioned and sponsored by ArcelorMittal, the world's largest steel producer.

Scope Definition of This Study

The scope of this study is to inform the comparative assertions on the environmental sustainability of the above-grade structural systems for tall buildings, quantifying the environmental impact of relative sectors in the building industry. The data used is consistent with the structural material quantities necessary to erect the above-grade structure of a tall office building, with a given shape that is subject to code-compliant wind and seismic forces. The referenced structure is hypothetically located in downtown Chicago, United States.

The functional unit for this study is represented by the whole structure of the building, corresponding to 246 and 490 meters in height (60- and 120-story equivalent scenarios). The "per net square meter" or "per floor" results are not considered in this study as the precise take-up of the floor area caused by the different structural systems can hardly be determined here. The study omits the occupancy phase of the building, and it is thus not applicable to a specific duration of use, as research evidence showed that the impact of the structural components during a building's use phase was not measurable, and the environmental performance of the building is predominantly controlled by other aspects of the design (function, curtain wall performance, MEP systems, etc).

Two different impact categories are considered for this study: Climate Change and Resource Depletion, with GWP and EE as their selected indicators.

The system boundaries of the study are extended to the whole life of the building structure, from the production and transportation of materials to the building site, through the construction and use phase (subsequently excluded from the results), the demolition of the building, and the recycling potentialities of the various components (presented as additional information since it is beyond the system boundaries set by European Norm 15978 "Sustainability of construction works – Assessment of environmental performance of buildings – Calculation method") (European Norm, 15978:2011).

Life Cycle Inventory Analysis

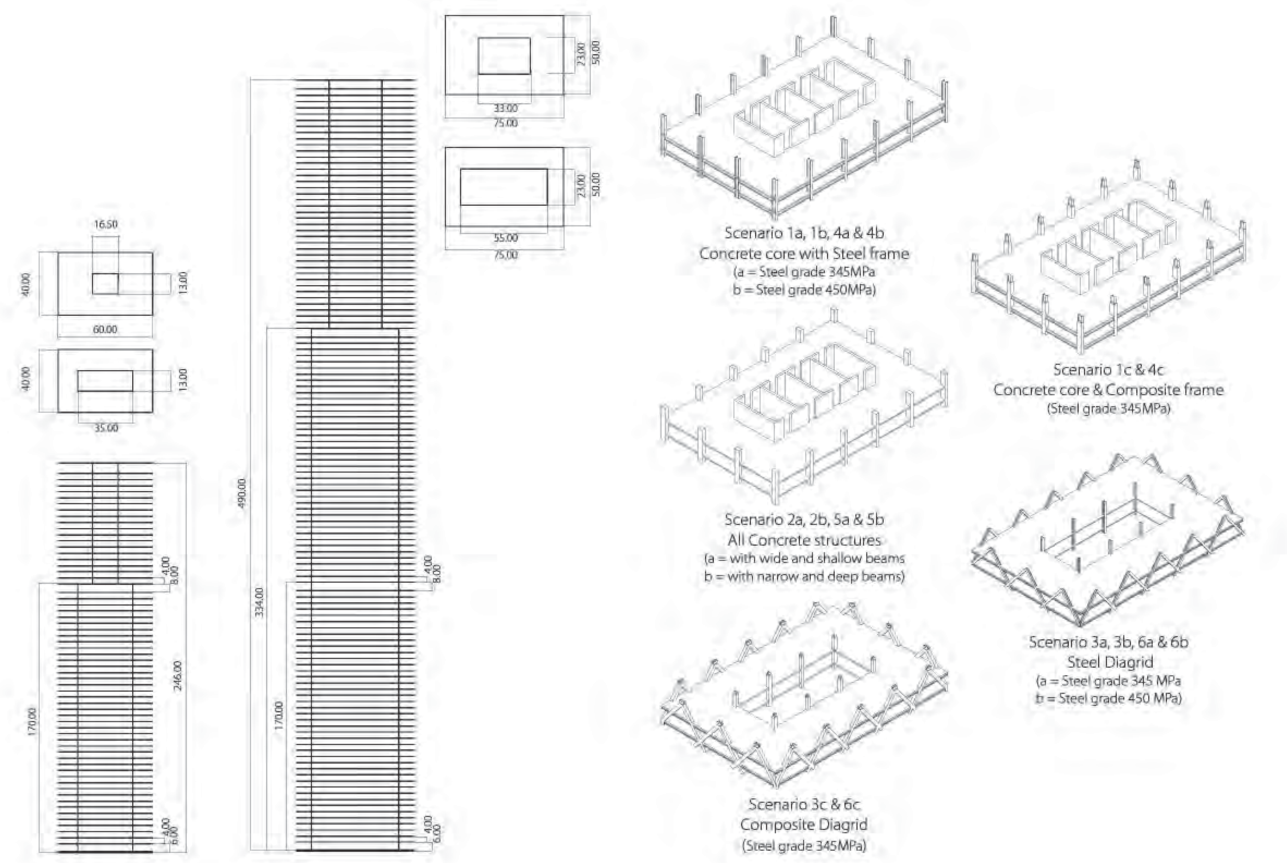
Quantities of Materials

The analyzed system is represented by the functional unit (i.e., the entire building structure) delivered by the construction company to the other contractors that will transform the structural skeleton for future use (interior fit-out, cladding, installation of MEP).

Inputs to the analyzed system were modeled by attributing the material quantities to the supply-chain of the construction company, represented by the material suppliers and the transport companies that deliver the materials to the site. With the use phase being excluded for the above mentioned reasons, the functional unit is then transferred in the end-of-life scenario to a demolition company, whose "inputs" (energy) and "outputs" (emissions and debris) are quantified.

Production of Materials

All the above mentioned quantities were calculated thanks to the support of several industry leaders who voluntarily contributed to the research by modeling specific structural scenarios. Inputs to the construction process, represented by the quantities of materials needed to construct the functional unit of this study, were calculated by some of the world's leading engineering firms on the basis of a design brief prepared by the CTBUH.



Top: Description of the 16 scenarios considered by the research.
Source: CTBUH

Eight different configurations for the vertical structure were identified for the 60-story tower, and eight for the 120-story variation. A total of 16 scenarios were thus identified, with each scenario submitted to two design firms, so as to obtain 32 "bills of materials" that represent the basis of information for the subsequent phases of this research. The resulting quantities were integrated with data on the horizontal structural elements (i.e., floor beams, floor slabs, etc.) obtained from a comparison with buildings of the same size, function, and scale to those considered for the research.

This phase regards the A1–A3 steps as described by the European Norm (EN) 15978 The results of this section, directly derived from participating engineering firms, are presented in Table 1.

Construction Process and Transportation Phase

The transportation phase was modeled on the basis of the real material transportation distances for the construction of a tall office building completed in 2009 in Downtown Chicago, for which the engineering firm responsible for the comparative real building was able to provide a comprehensive set of information.

Data for the on-site operations was calculated by contacting the suppliers of the largest machines operating on the building site during the erection of the structures (cranes and concrete pumps) to receive information on their energy consumption. This phase regards the A4–A5 steps as described by EN15978.

End of Life

The end-of-life quantities were obtained by consulting with three large demolition contractors operating at the international scale. Only the 60-story scenario was used in this circumstance as the demolition of such a building would still significantly exceed any previously demolished tall building. The same documentation that was provided to the engineering firms for the creation of the "bills of materials" was provided to the demolition firms in order to gather information on how a demolition project on this scale would be handled, which kind of machinery would be involved, and how long the demolition job would take.






In the wake of the flourishing innovation climate of the 21st century, the fundamental components of skyscrapers – and architecture in general – are undergoing dramatic changes. The tall building typology as we know it is being remodeled, with a renewed focus on environmental sustainability, economic efficiency, and social prosperity. This transformation is built upon the efforts of those who wish to see the tall building ascend beyond its current status into something smarter, more responsive, easier to construct, and infinitely more integrated into the urban habitat.

The Future of Tall is a collection of written works from the CTBUH 2015 New York Conference, which provide a glimpse of the many advances that are under development or already implemented in skyscrapers around the world. Inside you'll see how buildings are getting smarter, with integrated systems that allow them to operate autonomously. You will see how the evolution of vertical transportation will optimize the flow of people in a building and enable the creation of entirely new architectural forms. You will also see new techniques that will drastically change how we build and demolish skyscrapers.

One project that is pushing the boundary of skyscrapers in myriad ways, is the 314-meter MahaNakhon. This tower, rising in the Sathorn District of Bangkok, will accommodate residential and hotel functions and will be the tallest in the country upon completion. The "pixelated" recessions and extrusions wrapping their way up the tower create a signature appearance that will define the Bangkok skyline for years to come. The building represents a major leap forward, heralding a new era for a city that has urbanized heavily over its long history. Through buildings of this type, and the concomitant innovations that make them possible, we create a self fulfilling prophecy that simultaneously realizes dreams of the past and opens up new possibilities for the times ahead.

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