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Context to China's Legacy of Tall Building Development

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Editor's Note:
*This paper is one of 115 papers included in the proceedings of the CTBUH 9th World Congress in Shanghai. Many of the papers, including this one, were submitted in Chinese and translated. The proceedings will be available for sale after the Congress from the CTBUH Web Shop (**http://store.ctbuh.org**)*

Modern supertall buildings have become one of the vital symbols of economic development and the urbanization progress in mainland China, as well as one of the major focuses of China's construction industry. This paper reviews the context of modern supertall development in mainland China, evaluates development trends and stimuli, and analyzes evolving advancements. These factors will have a guiding significance on the future of China's supertalls and its fast-growing cities.

The rise of supertall buildings in modern Chinese architecture has a social context, as well as an economic and cultural background. Chinese ancestors relentlessly tried to conquer the highest mountains and the biggest rivers in order to challenge the order of nature. In this context, the Wooden Pagoda of Ying County, Shanxi Province (see Figure 1), is a high-rise prototype. Built in 1095 and extended in 1195, it rises to a height of 67 meters.

Since the beginning of the 20th century, modern commercial cities in China progressively emerged, and high-rise and supertall buildings developed as representations of the cities and their business advancements. Ever since then, these buildings have stepped onto the stage of history, sustaining the glorious view of the flourishing forthcoming 100 years.

Supertall buildings in mainland China are defined as buildings over 100 meters. According to the ***Code of Fire Protection Design of Tall Civil Buildings*** published in 1995, the code specification identifies the minimum height of all tall buildings to be 100 meters. Thus, the Chinese construction industry sets 100 meters as the minimum height for all supertall buildings. [***Editor's note:*** *The CTBUH defines supertall as a building over 300 meters, but this paper uses the Chinese definition.*]

The developmental thread for modern supertall buildings in China can be divided into four time periods:

1. Preparation Period, 1900 to 1949
2. Germination Period, 1950 to 1979
3. Development Period, 1980 to 1999
4. Prosperity Period, 2000 until present

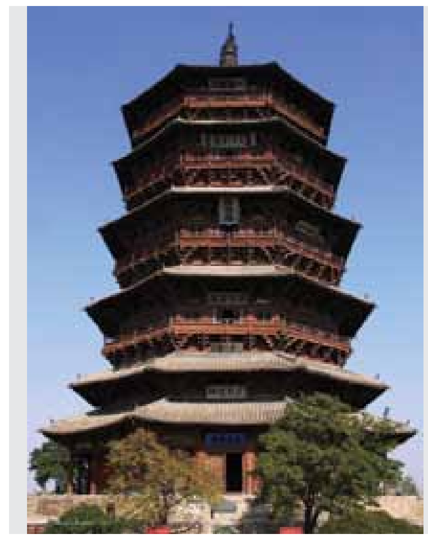

Figure 1. Wooden Pagoda of Ying County, Shanxi province. © Gisling

Through analysis and research, the three defining characteristics of each are building height, GDP per capita in major cities, and the number of completed projects. These characteristics can be used to depict the criteria for the four periods:

1. **Preparation Period:** building heights are below 100 meters;
2. **Germination Period:** an emerging breakthrough with the first supertall building height over 100 meters;
3. **Development Period:** building height breaking through 200 meters; GDP per capita in major cities reaches RMB5,000; the number of completed 200 m+ supertall buildings is less than 30;
4. **Prosperity Period:** building height breaking through 400 meters; GDP per capita in major cities reaches RMB25,000; the number of completed 200 m+ supertall buildings is more than 100.

An in-depth analysis of these four periods reveals four hidden developmental stimuli:

1. The impact of national economic development
   In the past 30 years, GDP grew from under RMB1 trillion in 1980 to RMB47 trillion in 2011. Real estate developments and investments exceeded RMB6 trillion. As a result of large investment stimuli, supertall buildings played one of the most important roles in the economic development of cities.

2. Impacts from urban population growth
   The effect of urban population concentration has become more prominent in the last 30 years. Urban population increased from under 100 million people in the 1980s to exceeding 350 million people in 2010. The urbanization rate reached 50% in 2011. New completed urban areas covered nearly 40,000 square kilometers at the end of the 2000s. As a result of intensive land uses, highly efficient, supertall buildings are gradually becoming a significant symbol of urban development.

3. Development of the Central Business District (CBD)
   The construction boom of CBD in megalopolises began with the River Delta Region in the 1980s and the Shanghai Pudong New District in the 1990s. Currently, the expanding Beijing CBD, the financial district of Yujiabao in the Binhai New Area of Tianjin, the Wangjiadun CBD of Wuhan, and the Hengqin new area CBD of Zhuhai are among the metropolises that have attracted a great number of financial institutions, international multinational corporations, large national companies and private enterprises in China. As a result of its high efficiency in business investment values, supertall buildings have been in favor with entrepreneurs.

4. Development of building technology
   The construction industry in China has made tremendous advancements in structural technology, earthquake and disaster prevention, elevator equipment technology, mechanical and electrical equipment technology, and construction technology.

In the past 30 years, a great number of code standards have been published. In regards to structural technology, there is the ***High-Rise Concrete Structure Technology Regulations and the High-Level Civil Buildings Steel Structure Regulations.*** For earthquake and disaster prevention, there is the ***Buildings Seismic Design Codes, High-Rise Construction Seismic Fortification Regulations*** authorized by the Construction Department No. 111 Regulation, and the ***Civic High-Rise Fire-Protection Design Regulations.*** In regards to elevator and related technology, publications include ***Specification for Electric Lifts and the National Standard of Safety Specification of Elevator Manufacture and Installation.*** Mechanical and electrical equipment is covered by the ***Code for Design of Heating Ventilation and Air Conditioning and the Standard for Design of Intelligent Buildings.*** For façade technology, there is the ***Technical Code for Glass Curtain Wall Engineering, Technical Code for Metal and Stone Curtain Wall Engineering, and Architecture Façade.***

Evolving Advancements of Modern Supertall Buildings in China

Each period in the development of tall buildings in China is characterized by key elements, as well as seminal projects that helped define the period.

Preparation Period (1900 to 1949):
Shanghai was the largest and most prosperous industrial and commercial city in China at this time. Shanghai was also the most developed construction region in China. The main construction projects included the Peace Hotel, also known as Sassoon House (see Figure 2). The 77-meter art deco building is topped by a pyramid, making it a distinctive part of the Bund. Built by Victor Sassoon, a member of the Sassoon banking family, it was the tallest building in China when it was completed in 1929. Today it is the Fairmont Peace Hotel Shanghai.

Figure 2. Fairmont Peace Hotel Shanghai. © Georgio

Other projects in the period include The Shanghai International Hotel (completed in 1934, 84 meters), and the Bank of China (completed in 1934, 84 meters).

In terms of structural technology, steel frames were primarily used for the main structures. In this period, the Shanghai International Hotel, the tallest building in China and Asia, was composed of a steel frame structure and reinforced concrete floors, with three parallel high-speed passenger elevators. The Otis passenger elevator was used in 1906 for the first time in the Shanghai Huizhong Hotel.

Germination Period (1950 to 1979):
After the People's Republic of China was founded, the Pearl River Delta Region became a significant source for international trade. New facilities and hotels were built for foreigners visiting the Canton Fair. The first truly tall building in China was the 114-meter-tall Guangzhou Baiyun Hotel, completed in 1976. Another significant high-rise building from the era was the Guangzhou Hotel (1968, 88 meters).

In terms of structural technology, the main structure of the Guangzhou Baiyun Hotel is a shear wall construction. A high-speed elevator was installed with a lifting height of 102 meters. At that time, high-rise building technologies were still in the exploratory phase.

Figure 3. Shanghai Centre. © ECADI

Development Period (1980 to 1999):
During this period, the Pearl River Delta region had its first breakthrough in supertall building construction, followed by the Shanghai region of the Yangtze River Delta , which was experiencing strong economic growth.

In the first decade of this period, the representational products in the Pearl River Delta region were the Shenzhen Development Center, completed in 1987 at 165 meters tall, and the Shenzhen International Trade Building, completed in 1987 at 160 meters. During this period, there were 12 tall buildings completed with heights between 100 meters and 200 meters nationwide.

In the last decade of this period, Shanghai, Guangzhou, Shenzhen and other cities participated in an interactive competition to build supertall towers with heights between 200 meters and 400 meters. The 421-meter Jin Mao completed in 1999, was the second tallest building in Asia and the third tallest building in the world. Other notable projects included the Guangzhou CITIC Plaza, completed in 1996 at 390 meters, and the 384-meter Shenzhen Shun Hing Square, completed in 1996. There were 124 tall buildings over 100 meters completed nationwide, including 27 of more than 200 meters.

During this period, high-rise building projects were small in quantity and scattered in location. The construction concept was based on the layout of one function for one building. Only exceptional cases like the Jin Mao and the Shanghai Center (completed in 1990, 164.8 meters, see Figure 3) explored multi-function designs and complexes.

In terms of structural technology, various forms coexisted. Taking the Jin Mao as an example, a "mega frame + core tube + outriggers" system was used, as well as the steel-concrete composite structure. Top-down construction methods were utilized. Fire-protection technology advanced with the release of the ***Code for Fire Protection of Civil High-Rise,*** which went into a trial phase in 1982 and formally implemented in 1995. Elevator equipment technology also improved, with the first VVVF Control Elevator in mainland China installed in 1988. Double-deck elevators were introduced in 1994, followed by the round-shape sightseeing high-speed elevator with three-cables and a speed of 7 m/s, followed by a 9 m/s super high-speed elevator. In the area of mechanical equipment, before the 1980s the air conditioning system composed of fan coils and air handling units were utilized. Cooling and heating sources were provided by centrifugal chillers and coal-fired boilers, or an urban heat supply network. Partial control systems were introduced for mechanical and electrical systems. By the 1990s, VAV air conditioning systems and the BA systems were used while coal boilers were replaced by fuel boilers.

Prosperity Period (2000 to present)
During this period, the economy of first-tier cities in the Pearl River Delta Region, Yangtze River Delta and the Bohai Bay Area continued to develop, while other second-tier cities started catching up. The total number of completed buildings over 200 meters was 143 and there were 331 buildings under construction. In comparison to the Development Period, this era had an exponential growth in the number of buildings constructed, which was hundreds more than the previous period. Construction principles and building technologies also gradually improved, supertall buildings entered the prosperity period.

The representational product in first-tier cities, such as Shanghai, Guangzhou, Shenzhen, Beijing, and Tianjin included the 492-meter Shanghai World Financial Center (see Figure 4), which became the tallest building in China when it was completed 2008. It was followed by the Shenzhen KK100 (completed in 2011, 442 meters), the Guangzhou International Financial Center (completed in 2010, 439 meters), and the Tianjin Global Financial Center (completed in 2011, 337 meters, see Figure 5)

The representational products in second-tier cities such as Nanjing, Wuxi, Wenzhou and Wuhan included the Zifeng Tower, Nanjing (completed in 2010, 450 meters, see Figure 6), the Longzi International Hotel (completed in 2011, 328 meters), the Wenzhou Trade Center (completed in 2011, 322 meters), and the Wuhan Minsheng Bank Tower (completed in 2008, 331 meters).

Two new patterns emerged in this period that are worthy of more in-depth comment: regional clusters and different building

Figure 4. Shanghai World Financial Center. © ECADI


Figure 5. Tianjin Global Financial Center. © ECADI


Figure 6. Zifeng Tower, Nanjing. © ECADI


Figure 7. China Central Place Hotel, Beijing. © ECADI

complexes, including commercial complexes and transportation complexes.

1. Regional cluster pattern

Based on overall planning and developmental principles, local governments began to develop regional clusters of supertall buildings. Representative cases include the Yujiapu Financial District in the Tianjin Binhai New Area (still under construction) and the China Central Place in Beijing (completed in 2008, see Figure 7), among other projects.

The Yujiapu Financial District of the Tianjin Binhai New Area has a planning area of 3.86 million square meters, taking up 120 land parcels with a total construction area of 9.5 million square meters. During the planning process, an overall plan integrated the space above and below ground, along with the transportation traffic. The space above ground adopted an appropriate road scale, road density and neighborhood characteristics; the underground commercial space included three vertical and two horizontal underground railway traffic systems to keep them interconnected.

The China Central Place in Beijing has more than 30 million square meters of space and cover more than one million square meters, including three super-5A intelligent office buildings, Ritz-Carlton and JW Marriott hotels, a Central Place Mall, and international apartment buildings, among other programmatic elements within the cluster.

2. Building Complex Pattern

This pattern integrates various functions in several buildings or a single building to form supertall building complexes. Representative cases include the Shanghai IFC North Tower (260 meters, completed in 2010) and the Tianjin Goldin Financial 117 (under construction, 597 meters) among other projects.

The Shanghai IFC complex is a combination of four buildings with a total floor construction area of 400,000 square meters. The building functions include two Class A office buildings, a Ritz-Carlton Hotel and a commercial building. The Tianjin Goldin Financial 117 is composed of a world-class level office building, a six-star hotel, an upscale shopping mall, business departments, exhibition center, and theaters.

During this period structural technology became more mature with the introduction of pure steel plate shear walls, steel supporting tubes, a tube-in-tube structure system, and a mega structure system. Steel - concrete composite structures became mainstream. For foundations, long pile and post-grouting techniques were used, along with a deep foundation pit technology. In terms of fire protection technology, performance-based evacuation applications and smoke simulation parameter technologies were used. Earthquake and disaster prevention techniques also improved. Energy dissipation technology, elastic-plastic time-history analysis, anti-progressive collapse, performance-based design, anti-explosion and wind-resistant design, and numerical wind tunnel simulation methods were used extensively, with an increasing emphasis on counter-terrorism technologies. In the area of equipment technology, gas boilers, energy storage technology, ground-source heat pumps, solar energy, fresh air cooling equipment, waste heat recovery, and rainwater utilization were among the various energy-saving technologies applied. Intelligent building systems and intelligent lighting controls were also fully developed.

Based on its steel-concrete composite structure, the Shanghai World Financial Center (WFC) utilized an economic and reasonable "core tube + mega column + outrigger" structural system. It included the first automatic wind damper device controllers installed in a supertall building in mainland China. It; it also installed elevators in mainland China at 10 m/s. During construction an integral steel

Figure 8. West Golden Eagle Plaza, Nanjing. © ECADI

platform modular system and an automatic hydraulic climbing formwork system were used with other systems.

The Emerging Trends of Modern Supertall Buildings in China

After the four periods of preparation, germination, development, and prosperity, there is no doubt that supertall buildings in China will become increasingly mature, continue to prosper, and break new records.

Guided by commercial demands, urban infrastructure and intensive land uses, supertall buildings will further explore the new concept of a "city in the sky."

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The innovative idea of the West Golden Eagle Plaza on the Nanjing River (under construction, 350 meters tall, see Figure 8) has formed a "city in the sky" prototype. The total area of the project will be 900,000 square meters which will include one office-hotel main building, two office buildings, and one commercial annex. The most unique feature is that the three main building complexes are connected in the sky at a height of 200 meters. A vertical transportation planning system is applied to the whole complex including elevated high-speed viaducts directly integrated into three levels above ground and a city subway is introduced beneath the buildings.

In the future, the new principle of a "city in the sky" will focus on population planning, industry composition, space distribution, energy, transportation, culture, health, low-carbonization, environment protection, and other aspects in order to improve the efficiency of the intensive usage of urban land.

During this new growth era, different technologies will be further developed and integrated into supertall buildings, including regional energy centers, numerical simulation technology on building environments, non-traditional water usage plans, networking technology and building energy consumption analysis techniques.

Figure 9. Dalian Greenland Center. © ECADI

Meanwhile, supertall buildings will continue to breakthrough new heights. The seven buildings over 500 meters currently under construction are: Shenzhen Ping An Finance Center (660 meters), Shanghai Tower (632 meters), Wuhan Greenland (606 meters), Tianjin Goldin Finance 117 (597 meters), The CTF Guangzhou (530 meters), Tianjin Chow Tai Fook Binhai Center (530 meters), and the Dalian Greenland Center (518 meters, see Figure 9). The list of projects in development also includes Wuhan Center (438 meters, see Figure 10), an original design produced by a Chinese architecture company.

Supertall buildings will become one of the most important mediums for further exploration and research of green and sustainable developments and the human living environment. The ***Technical Details of Green Supertall Building Evaluation,*** completed in February 2012, has become China's first guidance for reducing urban energy resources and micro-climate environmental impacts. The evaluation guide points out the future direction for supertall building developments with vital significance for China's cities. As the human representative of the highest technical construction achievements, supertall buildings should be an important experimental platform and vehicle to make contributions to the advancement of more low energy consumption methods and to create more beautiful living environments. ■

Figure 10. Wuhan Center. © ECADI