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### Architecture/Design

# Offset Cores: Trends, Drivers and Frequency in Tall Buildings





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#### Abstract

This research explores the trends, drivers and frequency of offset cores in the world's tallest buildings. It charts the history of tall building layouts, exploring the motivation behind offset-core morphologies emerging in the second half of the 20th century. Drawing from the literature, it then provides a definition for central, perimeter, mixed and offset cores, allowing for the categorization of the future 500 tallest buildings in terms of core position. It also identifies the tallest 20 buildings in the world with offset cores. The Hanking Center Tower in Shenzhen, at 358.9 meters in height, was confirmed as the world's tallest building with an offset core, as of the end of 2018. Given a recent increase in the vertical development of smaller sites in dense urban environments, and increased emphasis on passive design and environmental performance, the authors expect a greater diversity of core locations to emerge among the world's tallest buildings in the future.

Keywords: Tall Building Design, Offset Core, Skyscraper, Layout, Efficiency

### Background

The location of the service core in any tall building is one of the most fundamental design decisions, impacting efficiency, structural system, services, environmental performance, views, access and egress, and more. Yet, despite the opportunities available to the design team, the central-core skyscraper has remained a ubiquitous typology throughout history, predominantly due to the spatial and structural efficiencies such an arrangement offers.

In early skyscrapers that emerged out of late-19th- and early-20th-century Chicago and New York, a central core location was common due to a reliance on natural light and ventilation for comfort and productivity. Artificial lighting capabilities were poor and air-conditioning unviable in large commercial buildings until the 1930s (Oldfield et al. 2009). This meant the façade was the primary facilitator of thermal and visual comfort, with lease spans typically limited to between 6 and 8 meters to ensure access to light and air. With the façade conditioning occupiable workspace, the core was typically placed in the center of the building, since access to natural light was far more trivial in lift lobbies and fire stairs.

However, with the widespread development of mechanical conditioning in the postwar era, workspaces became liberated from the natural environment, and therefore the façade. This in turn liberated the high-rise service core from the center of the building. The Inland Steel Building (Chicago, 1958, SOM) was one of the first high-rises to capture the freedom that mechanical conditioning provided in terms of spatial layout and core position. Here, the core is offset far outside the primary building perimeter, into a distinct 25-story service tower. This freed the occupiable floor plan to be 18 meters wide by 54 meters long - totally unobstructed by structure or services. The concept was simple: to displace all interior obstructions, whether structural or mechanical, to the exterior of the building, creating the ultimate "open plan" (Abalos & Herreros 2003). A desire for unobstructed workspaces fueled the emergence of other offset-core towers, many becoming global icons, across the latter half of the 20th century (see Figure 1). Contemporary towers continue to use offset cores for these reasons. The Leadenhall Building in London (2014) – often referred to as the "Cheesegrater" – uses an offset core to provide open, flexible office space on a tight urban site. The offset core also becomes a key part of the building's visual identity,

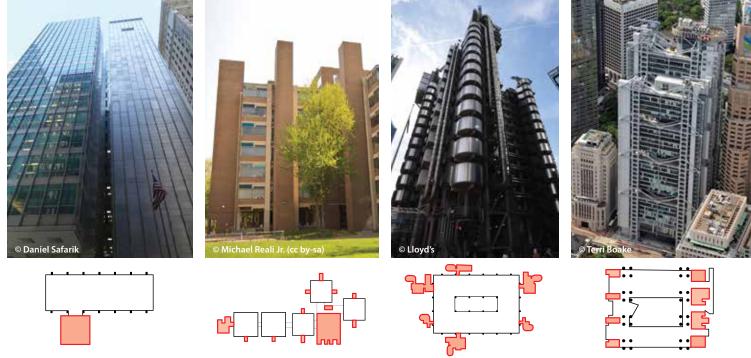


Figure 1. The rise of the offset-core tower in the mid-to-late 20th century. From left to right: Inland Steel Building, Chicago, 1958; Richards Medical Research Laboratories, Philadelphia, 1965; and Lloyd's Building, London, 1986; HSBC Headquarters, Hong Kong, 1985.



Figure 2. Offset north-facing core at the Leadenhall Building, London, with expressed vertical transportation and services. © Richard Bryant/British Land/Oxford Properties

with glazed elevators and colored steelwork providing a dynamic character to the tower's north façade (Young et al. 2013) (see Figure 2).

Beyond functionality, architects and researchers are calling for a greater diversity in core design and location for reasons of sustainability. Yeang (1999), for example, describes how core location can be a key driver to energy performance, noting that in hot and tropical climates, perimeter or offset cores can be used to self-shade occupied spaces, reducing cooling loads (see Figure 3). Such designs would also offer natural light, ventilation and views to service areas, such as lift lobbies and staircases, that

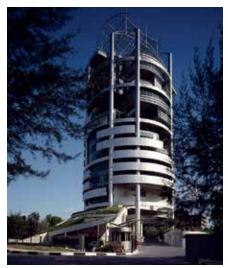


Figure 3. Menara Mesiniaga, Kuala Lumpur, 1992. An east-facing core, and deep west-facing brises-soleil, provide shade from the harsh equatorial sun path. © TR Hamzah & Yeang

are typically artificially conditioned, with little outlook or prospect, in the heart of the building.

While such innovation has long shown potential, most built examples of offset cores have been limited to outside the world's tallest buildings, where the central core typology dominates due to its inherent structural efficiency – providing lateral stability in the center of the building mass. However, the emergence of greater levels of structural innovation and heterogeneity in the world's tallest building designs is seeing taller and taller buildings emerge with alternative core placement for increased performance. In the design of the 358.9-meter Hanking Center Tower, the primary service core is offset outside the main perimeter of the building to increase open floor space, but also to provide a publicprivate gradient across each floor plate (see Figure 4). A hybrid braced tube provides the lateral support to achieve this unique supertall building arrangement (Xu et al. 2015).

This research seeks to explore these developments, examining innovation in core placement in the world's tallest buildings. It determines the location of the service core in the world's future tallest 500 buildings. In doing so, it identifies the frequency of offset-core skyscrapers emerging on skylines around the world and presents the current 20 tallest buildings with offset cores.

## Classification of Central, Perimeter, Mixed, and Offset Cores

The service core can be defined as "an element that gathers together the spaces necessary to provide visual, physical and functional vertical connections that work effectively to distribute services through the building" (Trabucco 2010). Effectively, this consists of areas that enclose some of the following elements: elevator banks, stairs, lobbies, toilets, service risers and plant rooms, along with some vertical and lateral structural components, such as megacolumns and shear walls.



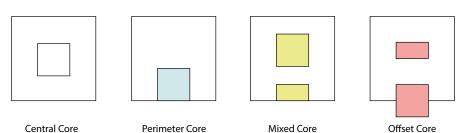
Figure 4. Hanking Center Tower, Shenzhen. © Hanking Group

A central-core building remains relatively simple to define. In a central-core building, the core location is inside the perimeter of the building form, surrounded on all sides by lettable floor area.

In a perimeter-core building, the service core is located on the perimeter of the building form, but does not project beyond it.

Some buildings have multiple service cores, allowing for hybrid definitions to evolve. Alternatively, stepped or tapered tall building forms may mean that a single core is in a central location for some of the building height, but on the perimeter at other levels. In this research, a mixed-core building is one which includes some core provision in a central location, and some core provision in a perimeter location.

Significant attention was given to the definition of offset cores, given the focus of this research. Since most offset-core buildings also include some core provision in a central or perimeter location, they could be considered as mixed-core buildings. However, in this research, any building that includes core provision projecting outside the primary building form is defined as an offset core. As part of this definition, three factors have been considered.



Central Core Perimeter Core Mixed Core Figure 5. Classification of central, perimeter, mixed, and offset cores in tall buildings

A tall building includes an offset core if:

- The core, or parts of the core, project beyond the building perimeter. In this instance, the building perimeter is considered the edge condition of the tower's floor plan. Some buildings with perimeter cores include shadow gaps or notches around its edge, giving the impression that the core is offset from the tower. However, as there is no true projection beyond the building's geometric form, in these instances the core location is considered to be on the perimeter.
- 2. Significant quantities of core provision project beyond the building perimeter. For a building core to be considered as offset, it needs to meet the definition as outlined previously by Trabucco (2010). This means a single offset stair or glass elevator outside the building perimeter does not denote an offset core, and "significant" quantities of building core provision need to be included in any offset area.
- 3. The core is offset for at least a third of the building's full height. In this instance, a tower-and-podium combination, with a core offset from the podium for only a few stories, would not meet the definition of "offset-core building".

This definition provides a degree of ambiguity in terms of classification. However, such subjectivity is necessary, given the wide variety of tall building layouts and designs permissible in the world's tallest buildings (see Figure 5). It is worth noting that few contemporary towers seem to have an entirely offset core, as typified by the Inland Steel Building, where all service core provision sits outside the building perimeter. This is due to modern building regulations governing the need for fire stairs and other service functions in close proximity to occupiable space.

### Methodology

The research started by identifying the world's future 500 tallest buildings. Future buildings were included in the study to allow for commentary on upcoming trends with respect to core location. The 500 tallest buildings were determined from the CTBUH Skyscraper Center database in June 2018 (CTBUH 2018). The list includes buildings that are completed, under construction and topped out, with heights ranging from 267 to 1,000 meters. Of the 500 buildings analyzed, 301 are classified as supertall (300 meters or higher). In order to determine the 20 tallest buildings with offset cores, the analysis was extended beyond the future 500 tallest towers, and included completed buildings down to a height of 247 meters.

Core location in each building was determined using a mix of research methods. Building plans and photographs were identified from the literature (published books and academic papers, unpublished research, etc.), web searches (building websites, real estate pages, etc.) and communications with design and development teams. In some instances, due to the incomplete status of the buildings on the list, plan drawings were not readily available in the public realm. In these cases, the core location was estimated from construction images and/or published visualizations.

### Findings

The tallest 10 offset-core buildings are illustrated in the Tall Buildings in Numbers section that follows on pages 46 and 47, with core positions highlighted in blue. The tallest 20 offset-core buildings are listed in Table 1. The entire dataset for the core location of the world's future 500 tallest buildings is presented in its entirety online at www.ctbuh. org/offset-cores.

This research has reinforced the initial assumption that the central core remains by far the most common building type, certainly in supertall buildings. Overall, of 500 buildings analyzed, 85% had a central core. Perimeter cores were the second-most common, comprising 10% of the buildings in this category. Offset-core buildings only made up 3% of the world's future 500 tallest buildings, with mixed cores making up the final 2%.

The world's tallest central-core tower is the Burj Khalifa, Dubai, at a height of 828 meters, which is also the world's current tallest building overall. The world's tallest mixed-core tower is the Shanghai World Financial Center, Shanghai, with a height of 492 meters. The world's tallest perimeter-core tower is the Burj Mohammed Bin Rashid Tower, Abu Dhabi, with a height of 381 meters. Finally, the world's tallest offset-core building is the Hanking Center Tower, Shenzhen, with a height of 358.9 meters. All these rankings are correct as of the end of 2018 - and are subject to change as new buildings complete in upcoming years. It is worth noting that the Hanking Center is not only the world's tallest offset core but also the "most-offset"-core building above 250 meters, with the core displaced some 10 meters from the perimeter of the main footprint. The 20 tallest offset cores display a wide range of plan arrangements, and ages, with five of the 20 buildings completed before the year 2000. The Chase Tower, completed in Chicago in 1969, is the world's oldest offset-core building over 250 meters in height. According to Campi (2000), the design was driven by the desire for unimpeded open public circulation at the ground level – although the client had initially resisted offsetting the cores, given they were trying to maximize rentable floorspace.

### **Conclusions and Further Implications**

While offset cores can provide both energy and functionality benefits to tall buildings,

**66**Few contemporary towers seem to have an entirely offset core. This is due to modern building regulations governing the need for fire stairs and other service functions in close proximity to occupiable space.**99** 

they remain an uncommon typology – certainly in the world's tallest towers. There are 376 buildings with a height over 250 meters completed as of the end of 2018, of which only 18 (4.8%) have offset cores. Yet, the researchers here speculate that two forces could see a change in future trends, with offset cores and diverse core typologies becoming more widespread.

The emergence of the "superslim" skyscraper Intense urbanization and high land prices in well-established vertical cities are seeing smaller land parcels being developed as tall building sites. One example of this trend is the emergence of "superslim" towers in New York, where skyscrapers less than 15 meters wide are achieving heights far in advance of supertall status, above 300 meters (Willis 2014). Given the limitation in terms of footprint in these buildings, a central core becomes spatially unviable, meaning a perimeter or offset core is often most efficient. While this trend has realised several new towers with perimeter cores (see Figure 6) its continuation could also see taller supertall towers with offset cores.

### Passive design and energy performance

Of the tall buildings that do employ an offset core, many do so in order to benefit from the spatial flexibility such an arrangement

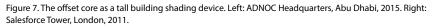
Rank	Building Name	Height (m)	Floors	Completed	Material	Use
1	Hanking Center Tower, Shenzhen	359	73	2018	composite	office
2	ADNOC Headquarters, Abu Dhabi	342	65	2015	concrete	office
3	Comcast Technology Center, Philadelphia	342	59	2018	composite	hotel/office
4	Longxi International Hotel, Wuxi	328	72	2011	composite	residential/hotel
5	The Index, Dubai	326	80	2010	concrete	residential/office
6	Abeno Harukas, Osaka	300	60	2014	steel	hotel/office/retail
7	Arraya Tower, Kuwait City	300	60	2009	concrete	office
8	JW Marriott, Panama City	284	70	2011	concrete	res./hotel/casino
9	Overseas Union Bank Centre, Singapore	278	63	1986	steel	office
10	Radisson Royal Hotel Dubai, Dubai	269	60	2010	concrete	hotel
11	Chase Tower, Chicago	265	61	1969	steel	office
12	Ningbo Global Shipping Plaza, Ningbo	262	52	2015	composite	office
13	Sapphire Tower, Istanbul	261	55	2010	concrete	residential
14	Vision Tower, Dubai	260	60	2011	concrete	office
15	Shenzhen Special Zone Daily Tower, Shenzhen	260	42	1998	concrete	office
16	The Masterpiece, Hong Kong	257	64	2009	concrete	residential/hotel
17	Rinku Gate Tower, Izumisano	256	56	1996	concrete/steel	hotel/office
18	Osaka World Trade Center, Osaka	256	55	1995	steel	office
19	Torre Cepsa, Madrid	248	49	2008	composite	office
20	Midland Square, Nagoya	247	48	2007	steel	office

Table 1.The 20 tallest offset-core buildings in the world.



Figure 6. The increasing trend toward superslim towers in New York has affected core position and plan form. From left to right: 111 West 57th Street, 2019; One Madison Park, 2010; 53 West 53rd, 2019; and One57, 2014.





provides. However, offset cores are also used for environmental benefits, often to provide shade in hot climates. Examples include the ADNOC Headquarters in Abu Dhabi (2015), where the east- and west-facing cores are clad in Bethel White granite to reflect solar gain away from occupied spaces, providing shade from the intensity of the sun (see Figure 7). Similar double-offset-core arrangements are used in The Index in Dubai (2010) and the Overseas Chinese Banking Corporation Centre in Singapore (1976). In tropical and hot desert climates, it is usually the east and west façades that require the most significant shading, due to the high sun paths in such regions. Yet it's not just in hot climates that the self-shading core can provide thermal benefits. Even in temperate climates, office buildings are often coolingload-dominated, due to the high internal heat gains they receive from people, computers and other equipment (Oldfield, 2019). In these climates, buildings such as the =Salesforce Tower, London (see Figure 7), and Poly Real Estate Headquarters, Guangzhou, use offset south-facing cores to act as solar shading, in order to reduce cooling energy needs.

Plan form and core location also has an intrinsic impact on natural ventilation capabilities in tall building design. Centralcore buildings are challenging to crossventilate, since the core provides a vertical obstacle limiting air flow. As such, many tall buildings that foster natural and hybrid ventilation strategies tend to use central atria, making use of the stack effect to draw fresh air into the building. With a void taking up the central location in the plan form, often cores are pushed to the perimeter, or into offset locations (see Figure 8).

Very few supertall buildings harness natural ventilation for comfort, due to the wide range of wind speeds and pressures prevalent over such heights. Yet, given the growing urgency to reduce our anthropogenic carbon emissions and avoid catastrophic climate change, it is likely that this could change, and even the world's tallest buildings will engage more with passive design. A shift away from the ubiquitous central core can contribute, with offset and perimeter positions providing opportunities for shade, or opening up space for atria to facilitate greater access to natural light and ventilation for deep occupied floors.

The challenge with supertall buildings is that their structural materials – concrete and steel – will likely make up a significant percentage of their lifecycle carbon footprint. The carbon embodied in a tall building's materials can make up to 33% of its total carbon footprint, a figure which will likely be much higher in the world's tallest skyscrapers (Oldfield, 2012). This means the most efficient structure, leading to the least quantity of materials, has an inherent environmental benefit. As such, the benefits of offsetting a core in supertall building design to provide shade, or greater access to natural ventilation for the occupants, needs to be carefully considered against the structural and material efficiencies that a central core system might provide.

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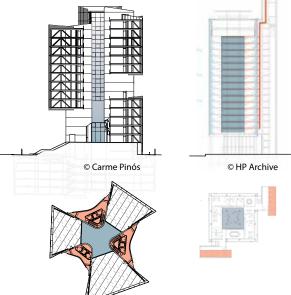
### References

ÁBALOS, I & HERREROS, J. 2003. *Tower and Office: From Modernist Theory to Contemporary Practice.* Cambridge: MIT Press.

CAMPI, M. 2000. *Skyscrapers: An Architectural Type of Modern Urbanism.* Zurich: Birkhäuser.

COUNCIL ON TALL BUILDINGS AND URBAN HABITAT (CTBUH). 2018. "The Skyscrapercenter." Accessed on February 13, 2019. http://www.skyscrapercenter.com/.

OLDFIELD, P. 2012. "Embodied Carbon and High-Rise." In *Asia Ascending: Age of the Sustainable Skyscraper City*: 614–22. Chicago: CTBUH.



OLDFIELD, P. 2019. *The Sustainable Tall Building: A Design Primer.* London: Routledge.

OLDFIELD, P., TRABUCCO, D. & WOOD, A. 2009. "Five Energy Generations of Tall Buildings: An Historical Analysis of Energy Consumption in High-Rise Buildings." *Journal of Architecture* 14(5): 591–613.

TRABUCCO, D. 2010. "Historical Evolution of the Service Core." **CTBUH Journal** 2010 Issue I: 42–7.

YEANG, K. 1999. The Green Skyscraper: The Basis for Designing Sustainable Intensive Buildings. Munich: Preste

WILLIS, C. 2014. "The Logic of Luxury: New York's New Sup Slender Towers." In *Future Cities: Towards Sustainable Vertical Urbanism*: 357–64. Chicago: CTBUH.

XU, Z., REN, C. & XIAO, C. 2015. "The Seismic Design and Non-Linear Dynamic Analysis of a 350 m High Braced Stee Frame." In *Global Interchanges: Resurgence of the Skyscraper City*: 561–8. Chicago: CTBUH.

YOUNG, A., ANNEREAU, N., BUTLER, A. & SMITH, B. 2013. "Te Light, and Handsome." *CTBUH Journal* 2013 Issue II: 13–7.

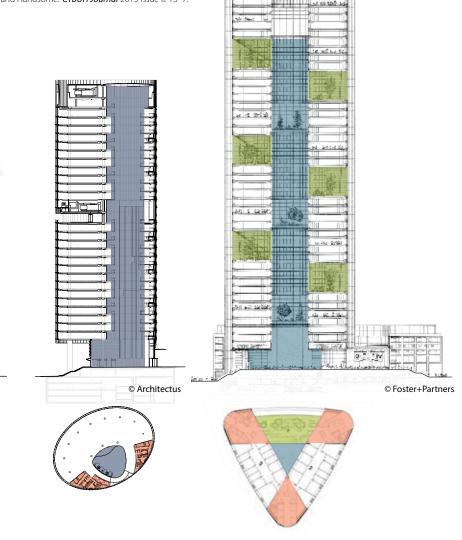


Figure 8. The use of central atria to facilitate natural ventilation in tall buildings, and its impact on plan form and core location. From left to right: Torre Cube, Guadalajara, 2005; DMAG Administration Building, Hannover, 1999; 1 Bligh Street, Sydney, 2011; and Commerzbank, Frankfurt, 1997.