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# Iconic Office Tower Propels Saudi Arabia into the New Global Century: Challenges and Innovations

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*As the centerpiece of the King Abdullah Financial District, the Capital Market Authority (CMA) Tower is evidence of the Kingdom of Saudi Arabia's economic diversification strategy. The faceted crystalline iconic structure, which rises 385 meters and 80 stories, serves as the headquarters of the Capital Market Authority, the government organization responsible for regulating Saudi Arabian capital markets. The design responds to the design guidelines and vision set forth by the developer of the district, the Al Raidah Investment Company. The region's climatic and environmental challenges inspired the development of a high-performance integrated enclosure system that incorporates solar shading, photovoltaics, façade lighting, and an innovative façade access system. Floor plates are designed to provide clear span lease depths that facilitate flexibility, efficiency, and natural daylight. An innovative vertical transportation system represents the world's first large-scale use of twin and double-deck elevators in one unique system. This integral sustainable design strategy is targeting LEED Gold certification.*

## A Financial Center in the Middle East

One of the largest and most ambitious commercial developments in the Middle East, the King Abdullah Financial District (KAFD) is a multi-phased mixed-use project that creates a world-class financial center for the Kingdom of Saudi Arabia and the entire region.

Located north of downtown Riyadh on a 1.6-million-square-meter site, the district seeks to diversify and advance the country's economy by bringing together the financial services sector and attracting foreign investment. It will position Saudi Arabia's capital city as the financial and economic nexus of the Middle East, on par with London's Canary Wharf and the world's other leading financial centers.

KAFD encompasses a gross area of approximately 3 million square meters of mixed-use development, including office buildings, a conferencing center, residential buildings, hotels, mosques, cultural facilities and museums, private recreational facilities, and a financial academy for training and developing the skills of Saudi youth. When

Opposite: Site plan of the CMA Tower viewed from above. Source: HOK

Right: Rendering of CMA Tower. Source: Bezier

completed, the district is projected to employ more than 75,000 people.

The urban planning of KAFD was carried out by Henning Larsen, inspired by the geological forms of the region and focused on the creation of pedestrian-friendly spaces (wadi) framed by densely massed buildings. A suspended monorail system connects the district's neighborhoods to each other, and a series of sky bridges link all commercial levels so individuals can efficiently navigate the community.

The centerpiece of the development – the Capital Market Authority Tower – is the tallest of the five buildings that make up the community's Financial Plaza. Rising 385 meters, the iconic structure has 73 occupied floors and a gross floor area of 182,137 sq. m. The building's anchor tenant is the Capital Market Authority, the government organization responsible for regulating the Saudi Arabian capital markets.

Designed by HOK/Omrania Joint Venture, the tower responds to the constraints and unusual site dimensions of the urban site parcel, which encompasses approximately 5,000 sq. m. in a trapezoid-shaped polygon. Design guidelines provided specific requirements on setback and build-to lines, podium and tower height, materials, sustainability goals, and connectivity with adjacent uses. The eastern portion of the site was designated as the tower zone, while the western portion was assigned to a podium. The design of the floor plate emerged from a desire to provide clear-span lease depths that would allow flexibility, efficiency, and access to natural daylight. The resulting hexagonal-shaped plan tapers inward and outward as it rises, providing floor plates that range from 2,500 to 2,600 sq. m. of gross floor area.

The resulting geometry of the faceted crystal-like structure acknowledges a desire to create a memorable image inspired from geologic formations polished by the hand of man. This language also applies to a podium

Bottom: View of CMA Tower under construction from the Northeast. Source: Omrania

Opposite: Floor plan and section of the tower. Source: HOK

structure whose faceted planes and shading elements (shroud) provide an ever-changing perspective from the ground level.
The tower structure merges into 6 main supporting nodes, which allow for more openness at the lobby levels, while expressing its elegant structural frame. By locating service functions below grade, the tower and podium support the creation of a dense urban environment that encourages pedestrian movement through the urban "wadi," and across pedestrian bridges, linking the building to a district wide monorail system.

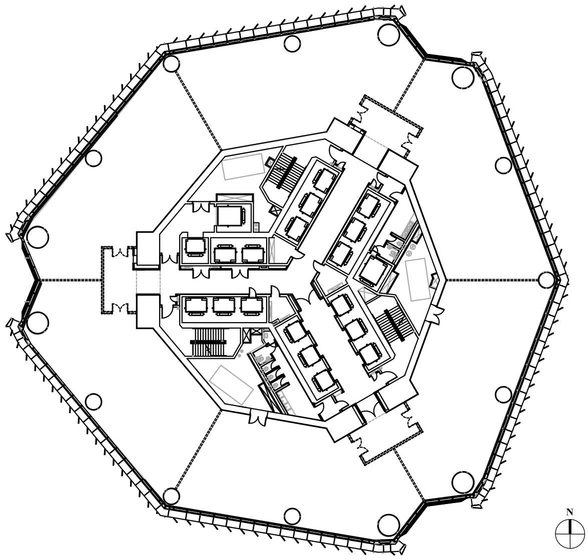
## Form and Function

The CMA Tower is dedicated to providing space solely for the use of office functions as well as fitness and swimming facilities located at level 54. Additionally, it contains a podium on the lower level that provides support functions such as an auditorium and cafeteria.

The iconic geometry of the building and its active façade provide an integrated design solution that contributes to a highly functional, yet strikingly original form on the skyline. Its unique shape also helps to reduce the phenomenon of vortex shedding, despite the fact that the tower does not significantly taper as it rises.

Tower floor levels are organized around the Y-shaped core, which incorporates vertical transportation, building services and emergency egress stairs. The body of the tower is organized into low-rise, mid-rise and high-rise sections. These divisions serve as the basic modules for many of the building systems and services, including vertical transportation, structure, mechanical, electrical, plumbing, fire protection and telecommunications.

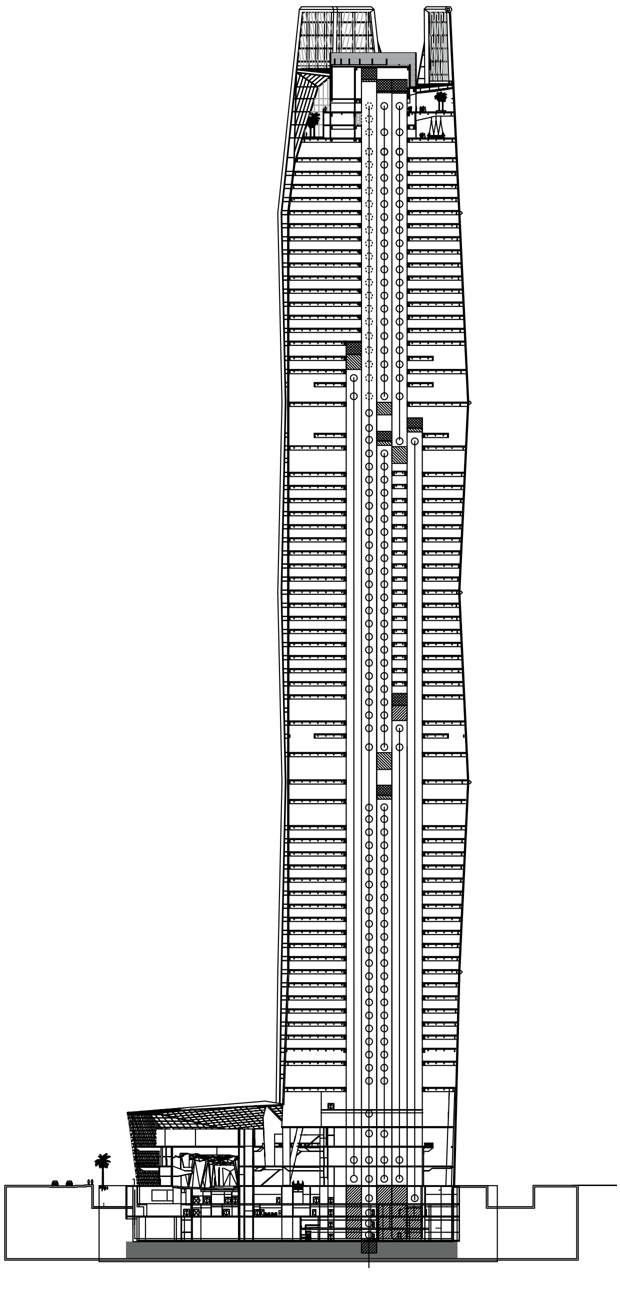
The tripartite organization of the tower also supports the project's anticipated tenant mix, which is expected to include approximately one-third multi-tenant floors, one-third single-tenant floors and the remaining upper levels occupied by anchor tenant CMA.





Because the office building is required to meet the functional needs of a variety of potential tenants, it must provide flexible floor plates that can be adapted to accommodate the diverse workplace requirements of individual organizations. To achieve this flexibility throughout the height of the tower, the design team carefully evaluated the geometry of each floor to optimize adaptability, flexibility, and efficiency. A rigorous approach to modular planning resulted in a tower design that provides clean, efficient, clear-span floor plates that maintain their efficiency across every level of the structure.

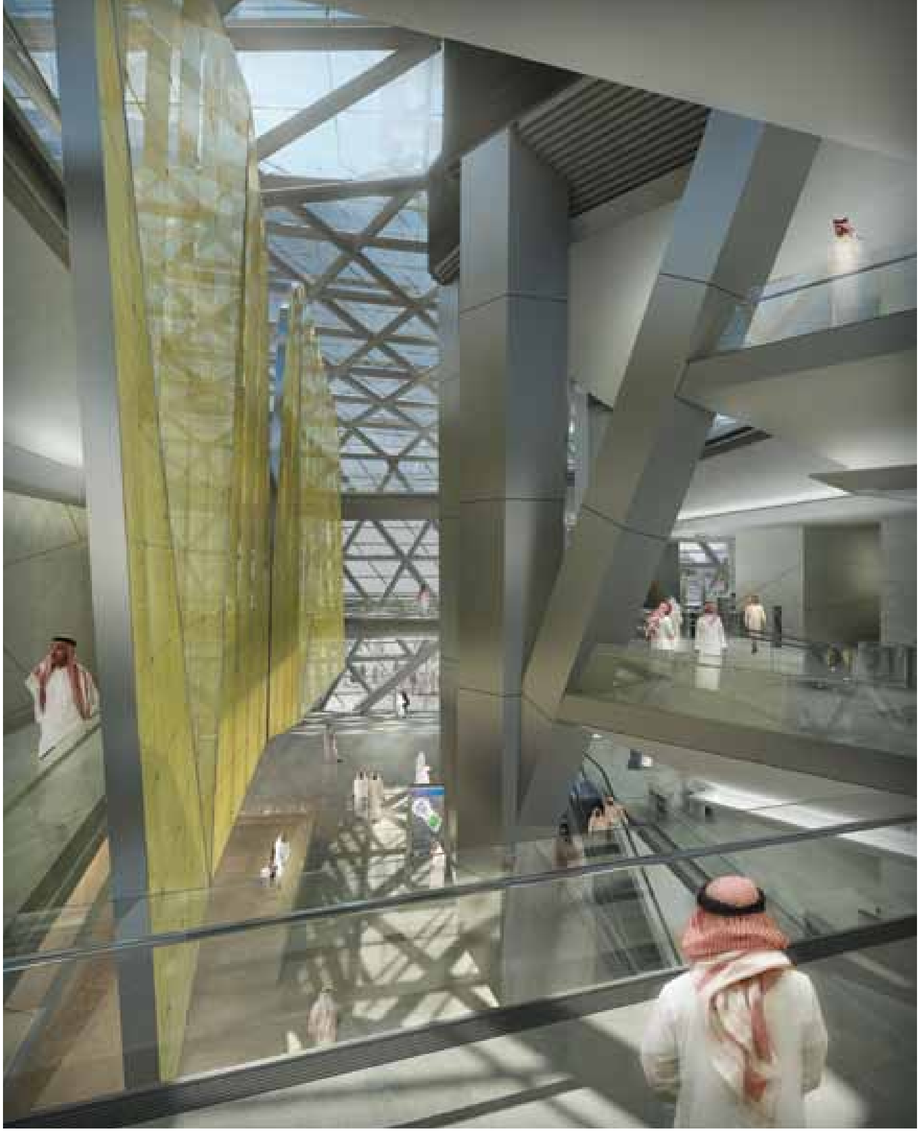
The interior design of the public spaces is integrated with the architecture to support a single aesthetic vision for the tower. A rich palette of materials based on warm neutral shades of gray complements the exterior materials while bringing both warmth and elegance to the space.



### Podium and Lobby Design

Conceived as a gemstone that has fallen from the tower and is leaning against it, the podium structure at the base of the tower integrates public circulation with private amenity spaces. Multiple functions in the tower's lower floors are arranged to provide public access to the tower elevator core and to house support functions required by tenants. These functions include a two-tier auditorium with a seating capacity of 400 as well as a 220-seat cafeteria divided into male, female, and VIP sections. Site constraints required vertical stacking of functions, though KAFD regulations limited overall height.

A 22-meter-tall atrium links the pedestrian entrance from the Financial Plaza with the motor drop-off zone on the north access road. Inspired by the natural landscape form of a canyon, the atrium serves to organize movement into the lobby on the east and the support functions in the freestanding podium on the west. The monumental scale of the tower columns, which converge



into three primary tripod supports, defines the interior character of the atrium. To the west, an art sculpture screen serves as a delicate counterpoint to the robust structural expression. Bridges span across the atrium, connecting the upper levels of the lobby with the cafeteria, located at the upper floor of the podium.

Escalators provide access to the dual-deck elevators. The public is directed to the appropriate elevator cab by a system of destination dispatch, which automatically organizes flows to the proper floor or sky lobby. The escalators surround the core structure and are visible from the exterior, providing views to activities within the building and events in the plaza.

Complementing the faceted massing and skin of the tower, the freestanding podium is designed to be admired as a finely detailed object from all views, including from above. The vertical "pleat" of the tower becomes a horizontal pleat on the podium roof, and the folded surfaces suggest the folded nature of the diamond-shaped surfaces of the tower. While the floors are supported with a simple system of columns and slabs, the exterior surface is supported by a diagrid steel structure that wraps the mass exterior walls and roof. This structure is in turn covered in high-performance, triple-glazed glass filled with Nanogel® aerogel, providing additional thermal insulation. Finally, the glass is shaded by a shroud consisting of 3mm-thick perforated metal panels to provide a comfortable filter for light throughout the podium, and in particular, through the cafeteria ceiling. This complex array of systems and functions has been carefully integrated into the design to maximize the use of the site, provide a grand entrance to the building and accommodate the functions required at the ground.

The four below-grade levels accommodate major utility entry points, the loading dock, and building maintenance and service facilities. A

Opposite Top & Bottom: View of Atrium space between the podium and tower lobby. Source: HOK

Bottom: Podium render showing vertical and horizontal "pleats." Source: HOK

***"The iconic geometry of the building and its active façade provide an integrated design solution that contributes to a highly functional, yet strikingly original form on the skyline. Its unique shape also helps to reduce the phenomenon of vortex shedding, despite the fact that the tower does not significantly taper as it rises."***

commercial grade kitchen – housed on level B2 – is linked to the loading dock and waste management areas of the dock with separate "clean" and "soiled" elevators.

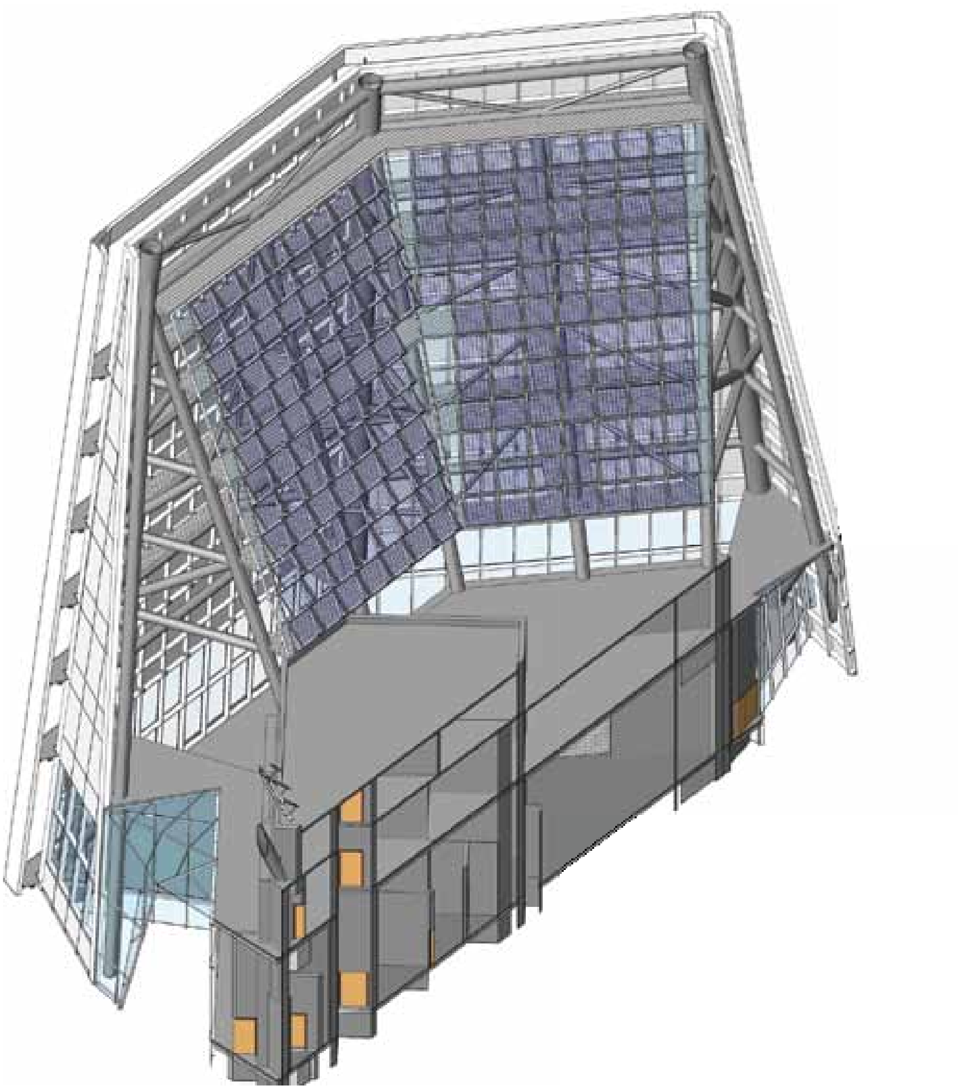
Limestone paving and raised planters that radiate from the central feature of the Financial Plaza anchor the east side of the tower to create small, shaded spaces for gathering. The main drop-off area along the north elevation creates a unique experience separated from the main roadway to allow for safe entrance and exit from vehicles in a secure area. A VIP entrance located to the south of the building allows for drop-off along the Financial Plaza once occupants or visitors pass through security at either the east or west ends of the plaza.

### Exterior Enclosure

The harsh environmental conditions present in Saudi Arabia pose unique challenges to the design of supertall buildings. The greatest factor affecting comfort conditions and energy use is the intense solar radiation common to the area. This radiation results in significant energy used to cool interior spaces and extensive use of artificial lighting because windows are covered to minimize heat gain. In addition, buildings with a large mass absorb heat during the day and continue to re-radiate heat into the interior of the building long after the sun has set. At the same time, occupants and visitors expect supertall buildings to offer outstanding, unobstructed views to the outside.

An additional challenge posed by the local environment is the accumulation of dust, which is commonly present in the air and particularly extreme during seasonal sandstorms. This fine-grain sand clings to building surfaces, obstructing visibility as well as affecting the performance of photovoltaics. This phenomenon requires buildings to undergo frequent exterior cleaning, a burdensome task because of the region's limited supply of water resources as well as the high cost of equipment and manpower.

The design team addressed these formidable challenges by implementing a high-performance enclosure solution that incorporates solar shading, photovoltaic solar collection, façade lighting, and an innovative façade access system. This



integrated enclosure solution reinforces and reflects the overall building design as well as its geometry and identity.

The major components of the system include:

1. A triple-glazed insulated glass unit (IGU), unitized type glass curtain wall.
2. A horizontal gantry, or catwalk, located on each floor.
3. An array of angled glass fins connected to the gantry for shading.
4. A photovoltaic farm located in the crown of the building.
5. A custom building maintenance unit system.

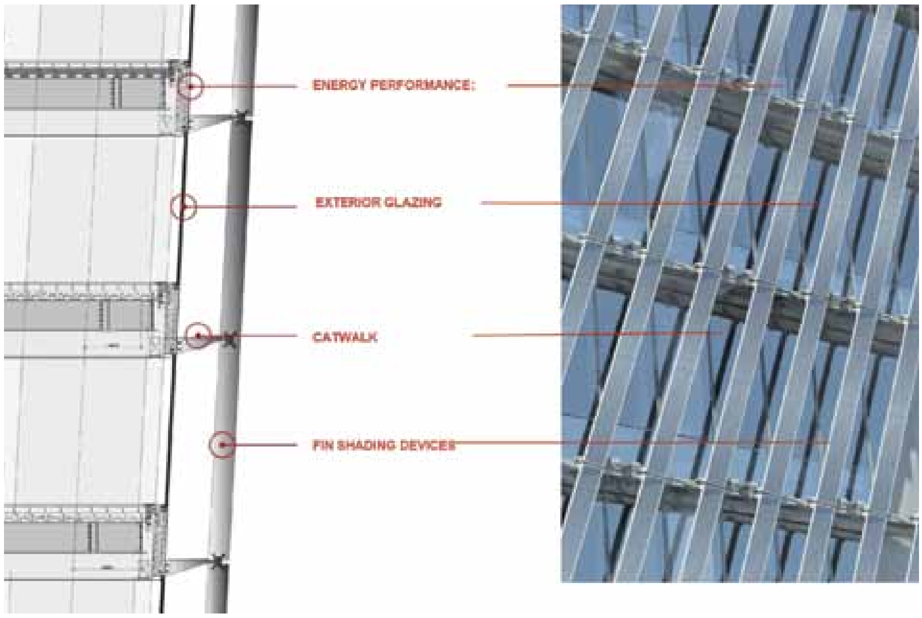
In order to achieve the energy performance goals for the building, the solar heat gain coefficient (SHGC) was set at optimum levels to deliver an efficient façade system. This aim required the combined work of a triple-glazed IGU system with high-performance glass, along with an effective shading system. This system consists of a polymerizing vinyli denedi fluoride (PVDF) coated aluminum grated catwalk, to which are connected vertical 400mm deep glass fins with offset frit pattern. The fins are optimized both in their plan position and sectional angle to account for the solar tracking, significantly reducing direct solar incidence on the conditioned enclosure. This assembly is able to meet the required shading factor criteria while also providing a respectable visible light transmission of 35%, without compromising exterior views.

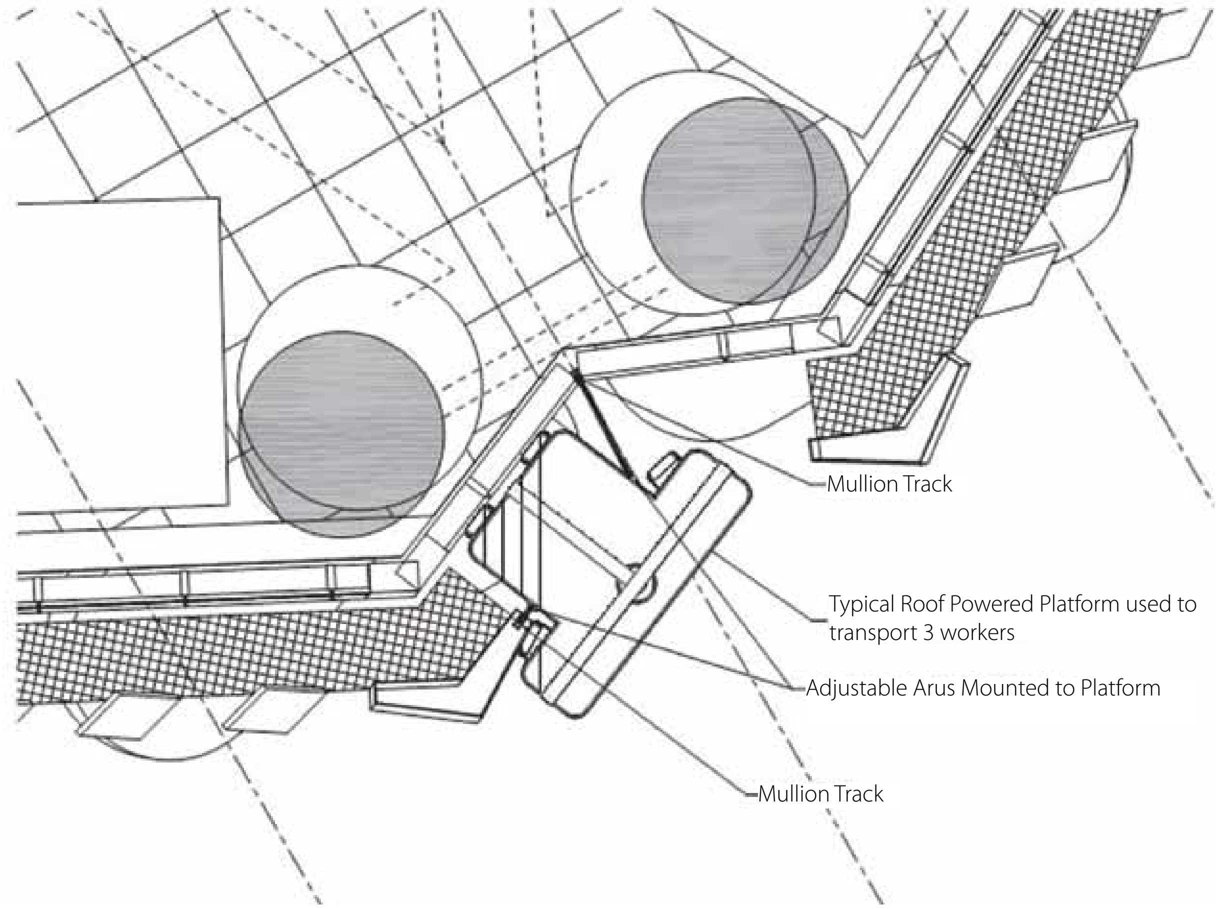
Three building maintenance unit (BMU) devices located at the top of the building are able to "luff" up at such an angle as to reach over the petal walls if necessary and also allow access to the PV panel array at the roof. These BMU's support three platforms that are connected to a vertical track system located at the metal "pleat." The arms attaching the platform to the mullion track are adjustable to allow the platform to track the catwalk and chevron pattern as it descends. Suspended from each catwalk is a monorail track that enables maintenance workers to connect a retractable lanyard to a safety harness, allowing them to dismount the platform safely to access and walk along the catwalk. A cart to secure cleaning equipment and supplies is designed to roll along a track at the catwalk level. This system is also

Opposite: 3D render of the PV panel array. Source: HOK

Top: Detail of CMA Tower's enclosure system. Source: HOK

Bottom: Plan detail showing the access platform connected to a rail on a "pleat." Source: HOK



designed to provide safe and efficient access for glass replacement. Introducing the catwalk as one of the major façade elements contributes toward the increase of the cleaning cycle frequency from 4 times per annum to 15 times per annum, which is calculated with three BMU's on the roof with capacity for three workers per platform.

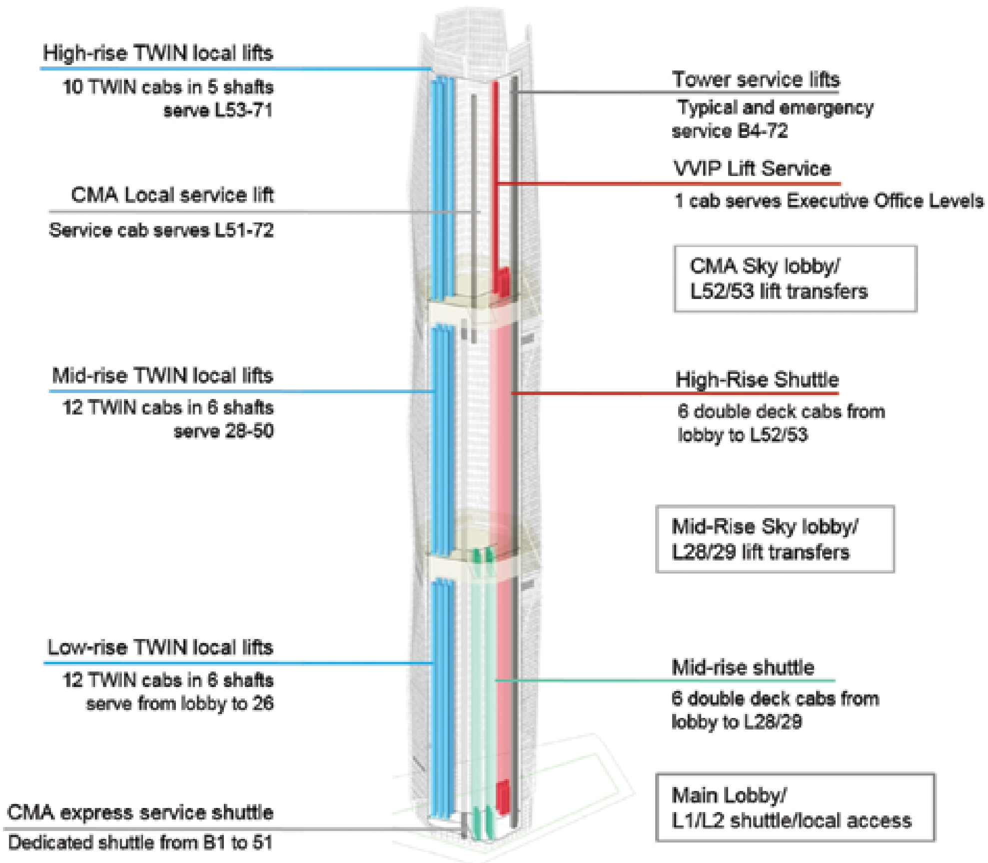
Eliminating copper-wire-based distribution systems for data and security further reduces internal heat gain. The design uses the "cool" technologies of wireless communication, air-blown fiber optics and converged networks. The intelligent infrastructure merges voice, data and video networks to reduce costs, centralize management and boost productivity.
To accommodate future expansion and upgraded technology, all systems have redundant capacity.

## Vertical Transportation

Site constraints challenged the design team to create an efficient floor plate design within a fairly restricted floor-plate area, ranging from 2,500 to 2,600 gross sq. m. per floor. To meet the goal of achieving a blended efficiency ratio of 70 percent gross-to-usable space required minimizing the area utilized in the core, where the elevator banks are the key driver of size requirements. Initially the design team proposed a series of elevator banks both inside and outside the core, radiating in a pattern of spokes, which would drop off as the tower rose in height. But this concept negatively affected the floor efficiency and flexibility of use.

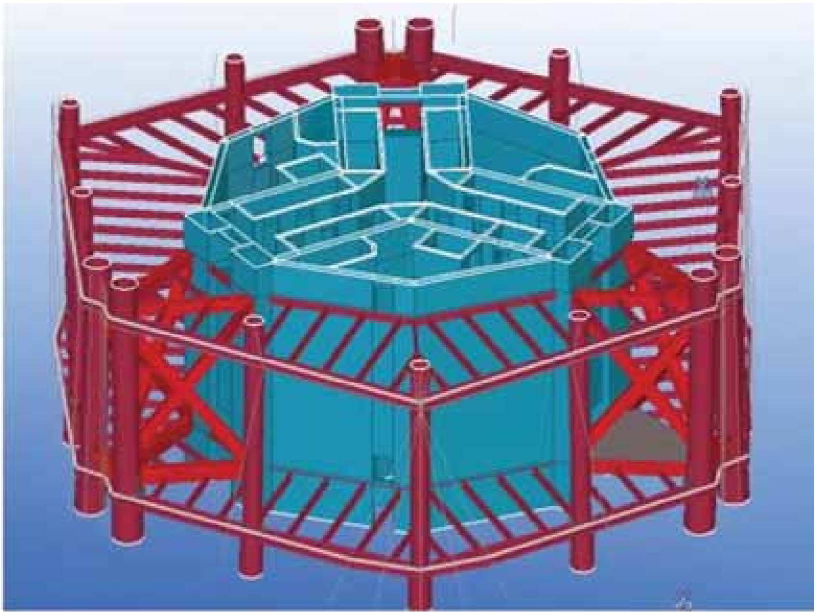
The solution integrates the twin elevator technology for local zone elevators. This system is characterized by two elevator cabs traveling independently – one above the other – in the same shaft. The benefits to the design include a decrease in the number of shafts and a decrease in travel time.

Divided into three office zones, the tower includes one group of six TK Twin passenger lifts in each of the lower and middle zones of the building. The lower and zone serves levels L1, L2,L3, X, 5-24 and the middle zone serves levels 26-51. Each of these groups contains elevators with a capacity of 1600kg/1600kg and speeds of 3.5 and 5 m/s. The upper zone contains five shafts consisting of four TK Twin lifts and a single deck lift. The four TK



Opposite: Elevator system configuration showing use of double deck and TWIN cabs. Source: HOK

Below: Structure diagram showing the central core and steel framing for the outrigger configurations on service floors. Source: HOK



Twins have a capacity of 1600kg/1600kg and speeds of 3.5 and 5 m/s.

The middle and upper zones are accessible via double-deck sky lobby shuttles. Each of these local zones is supplied with destination dispatch monitors. The sky lobbies are accessed via fixed double-deck lifts using destination dispatch. The mid sky lobby shuttles serve levels L1, L2, X, 28 and 29 with a capacity of 1600kg/1600kg and a speed of 5.0 m/s. The upper sky lobby shuttle serves levels L1, L2, L3 X, 52 and 53 with a capacity of 1600kg/1600kg and a speed of 7 m/s. Service lifts serve all floors of the tower and include an oversized lift for firefighter access.

This system meets the minimum level of service for a modern office building, comparable to Class A office properties within the commercial real estate market. Average wait times of less than 21 seconds, with a minimum handling capacity of 12 percent, translate to an "excellent" classification.

Additionally, four service elevators are provided to serve the lower and upper halves of the building. One of these elevators is oversized for maintenance servicing and provides access to all service zones when required.

This design represents one of the largest installations of the twin system of elevators integrated with double-deck shuttles, and its application to the unique conditions of site, building area and height have resulted in significant savings of circulation area and improved service, contributing toward the overall efficiency and sustainability of the building.

## Photovoltaic System

On the roof of CMA Tower, an array of solar panels will be installed to reduce the consumption of power and rely on solar technology for a portion of its energy requirements. To be installed in accordance with national electrical code (NEC), the photovoltaic system will generate energy that will cover more than 1.0% of the total annual project electrical consumption cost and will satisfy LEED certification requirements in relation to site-renewable energy under LEED-CSV 2.0. The photovoltaic system will transfer the solar emergency to AC power supply through inverters fixed at rooftop level. The power generated will be interlocked with main low voltage power supply of the building in accordance to NEC requirements article 685.

Approximately 400,000 Kilowatt hours of clean energy will be generated each year, which will contribute toward the total power assumption of the building and will be fed into the power grid via 12 PV inverters (10kw A.C 230V single phase 60 Hz). The solar panels will prevent the emission of 216 tons of $CO_2$ annually once it is connected to the grid upon the building's completion.

## The Structural Skeleton

The building's 385m high main structural skeleton comprises a central core, perimeter columns, composite floors, roof crown and a continuous raft foundation. The central core is made of cast in-situ reinforced concrete walls interlinked in a hexagonal-shaped pattern by coupling shear beams. The core serves as a backbone to the tower, and resists both gravity and lateral loads. The average thickness of the core walls is 1,500 mm at basement levels, reduced to 600 mm at the top of the tower.

15 concrete-filled steel tube perimeter columns support gravity loads. In order to

enhance the overall lateral stability of the tower, six major perimeter columns are linked to the central core to share a portion of the lateral load resistance. This link is achieved by two levels of outrigger trusses allocated at the services floors. All perimeter columns are inclined to follow the faceting geometry of the architectural enclosure and are skewed below level five to form six main supporting nodes at level one to serve the aesthetical and functional requirements. Column diameters range between 1,800 mm to 2,400 mm at lower floors and are reduced to 1,500 mm and 1,800 mm at the top of the tower below the crown base.

A 21,500 mm high roof crown is designed as an extrusion of the perimeter columns extending to the top of the tower structure. The crown is made of structural steel space trusses supported by the perimeter columns and the central core.

The typical floor framing outside the core area consists of 610 mm deep structural steel I-shaped beams acting compositely with a 180 mm thick reinforced concrete slab on a metal deck, while the inside core area framing comprises cast in-situ reinforced concrete slabs of an average thickness of 200 mm and 700 mm deep reinforced concrete beams. At tie-floors, where perimeter columns change angle of inclination, additional floor beams are introduced to act as tying elements and support gravity loads simultaneously. Tie floors consist of 500 mm deep steel box tie-beams filled with concrete, and 457 mm deep steel I-shaped beams acting compositely with a 180 mm thick reinforced concrete slab on a metal deck.

The tower is supported on a continuous thick cast in-situ reinforced concrete raft foundation with uniform thickness of 4,000 mm, increased to 4,500 mm below the six mega columns, and bearing directly onto the rock strata underneath.

As one of the world's tallest and most advanced commercial structures, the CMA Tower makes a profound statement about Riyadh, Saudi Arabia, as the financial capital of the Middle East. The building also advances an iconic design that effectively addresses the region's climatic and environmental challenges through creative and unique technical solutions. Its signature role in the KAFD District, high-performance integrated enclosure system, flexible interior environment, and innovative vertical transportation system serve as an influential global benchmark for supertall buildings.

Top: Overall view of the building in context. Source: HOK

Opposite: Detailed view at night. Source: HOK

*“The tripartite organization of the tower also supports the project’s anticipated tenant mix, which is expected to include approximately one-third multi-tenant floors, one-third single-tenant floors and the remaining upper levels occupied by anchor tenant CMA.“*