Economics Planning of Super Tall Buildings in Asia Pacific Cities

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Key words: economics planning, super tall building, Asia Pacific

SUMMARY

The purpose of this paper is to study the economics planning of super tall office buildings in Asia Pacific cities. This study is based on the case study of the Asia Pacific's 10 tallest buildings which are distributed over six major cities. All are landmark buildings with similar functions.

From the analysis of the collected data, the floor plate of these buildings is comparatively large, thus achieving a fairly high lettable to gross floor ratio of about 80% and low wall to floor area ratio of about 0.33. The most common lease span is approximately 12m with column-free between its service core and exterior window. The most common floor-to-floor height is about 4.0m. Square or similar plan is the most common geometry in super tall buildings since this geometry offers the same stiffness in both directions against lateral wind forces. Typically the building is in form of a large podium at lower levels with a setback in the overall floor plan dimension in the main tower and a slightly tapered shape at its top floors.

The central core approach in which the core is designed as a structural element to provide stability is commonly used in super tall buildings. By using slip-form or jump-form techniques, a 3 to 4-day cycle is achievable for core wall construction which is similar to steel construction. Either composite mega-columns with central core and outriggers system or reinforced concrete tube-in-tube with or without outriggers system is able to achieve the world's tallest buildings. However, high-strength concrete is fairly common in many Asia Pacific countries.

In order to keep the service core within a reasonable size while maintaining an acceptable level of life response time, the sky-lobby system is commonly adopted as a solution. Another solution is to use the double-deck lift system.

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1. INTRODUCTION

The Sears Tower has been the world's tallest building for over 20 years. After the completion of some even taller buildings such as the Petronas Towers and Taiper 101 Tower, the United States has no longer dominated the design and construction of super tall buildings. Among the world's ten tallest buildings, seven buildings are in Asia Pacific cities. This may reflect that peopele in Asia Pacific cities are keen to build the world's tallest buildings in response to high land values and the technical and political prestige associated with sheer height.

Super tall buildings are generally large in scale, complex in nature and more expensive in construction and thus its economic planning is particularly important. Few previous studies on the economic planning of tall buildings were conducted in western countries. However, the economics considerations vary from location to location and therefore, previous studies may not be applicable to Asia Pacific countries. There is also no previous study on "super" tall buildings which require unique considerations. Therefore this study aims to examine the economics planning of super tall office buildings in Asia Pacific cities.

2. RESEARCH METHOD

In Asia Pacific cities, tall buildings may be generally classified in the range of 30 to 50 stories and buildings in excess of 50 stories may be considered as super tall buildings. However, there is no universally accepted definition for super tall buildings. Instead of providing a debatable definition, this study is based on the Asia Pacific's 10 tallest buildings according to Emporis Building and Skyscraper Page's records (as at January 2007) as shown in Table 1. It is noted that these buildings also represent the world's 15 tallest buildings and are undoubtedly be considered as super tall buildings. In addition, many of these buildings are also the tallest buildings in its cities. All are landmark buildings which were designed by internationally renowned design consultants and should reflect some good practices in respect of its economics planning.

This study was based on the case study method. The relevant building data was collected by means of questionnaires sent to building clients, architects, engineers and quantity surveyors. The questionnaire consists of two sections. Section one covers the general information of the building including the name of the building, its location, names of building client, architect and engineer, completion date and its functions. Section two seeks to collect information on the building planning including the floor layout, gross and net floor areas, floor-to-floor height, lease span, service core planning, structural system, construction method and vertical transportation system. Other resources such as magazines, journals, books and Internet were also gathered for these buildings.

	Building	City	Height	Floors	Year
1.	Taipei 101 Tower	Taipei	509 m	101	2004
2.	Petronas Tower 1	Kuala Lumpur	452 m	88	1998
3	Petronas Tower 2	Kuala Lumpur	452 m	88	1998
4	Jin Mao Tower	Shanghai	421m	88	1998
5.	2 International Finance Centre	Hong Kong	415 m	88	2003
6.	CITIC Plaza	Guangzhou	391 m	80	1997
7.	Shun Hing Square	Shenzhen	384 m	69	1996
8.	Central Plaza	Hong Kong	374 m	78	1992
9.	Bank of China Tower	Hong Kong	367 m	70	1990
10.	The Center	Hong Kong	346 m	73	1998

Table 1: Asia Pacific's 10 Tallest Buildings
Adapted from Emporis Building (as at January 2007)

3. DATA CHARACTERISTICS

By geographical location, the sampled buildings are distributed over six major cities, namely, Taipei, Kuala Lumpur, Shanghai, Hong Kong, Guangzhou and Shenzhen. It is noted that the Taipei 101 Tower, Petronas Tower, Jin Mao Tower, 2 International Finance Centre, CITIC Plaza, Shun Hing Square are the tallest buildings in Taipei, Kuala Lumpur, Shanghai, Hong Kong, Guangzhou and Shenzhen respectively.

Functional requirement is the principal factor in the planning of tall buildings as it dictates the lease span, building form, floor-to-floor height, core planning and vertical transportation. It is found from the collected data that the main tower of these buildings is primarily designed for office function, except the Jin Mao Tower which is a combination of hotel and office and also that some buildings such as the Petronas Towers, Jin Mao Tower, 2 International Finance Centre, CITIC Plaza, Shun Hing Square and Centre comprise retail/commercial function at its lower basement/podium floors. This similarity in function allows meaningful comparison among the sampled buildings.

As shown in Table 1, the number of floors ranges from the 69-storey Shun Hing Square to 101-storey Taipei 101 Tower, whereas the building height ranges from 346m (the Centre) to 510m (Taipei 101 Tower). These buildings were built between 1992 and 2004; the earlier and latest completed buildings are the Central Plaza and Taipei 101 Tower respectively. Thus the design of these buildings can represent the latest technology.

4. FIDNINGS AND DISCSSIONS

4.1 Size of Floor Plate

The size of the floor plate is primarily determined by the user's requirement subject to various statutory constraints. For instance, the building regulation may stipulate the permitted maximum site coverage which in effect limits the size of the floor plate in relation to its site area. The building regulation may also stipulate the maximum travel distance from the farthest point on a floor to a protected stair. The major considerations behind the economics of floor plates are the lettable (or rentable) to gross floor ratio and the wall to floor area ratio.

The lettable to gross floor ratio depends on the size of the floor plate in relation to its service core. Thus the two main components are the usable space to be occupied by the tenant and the service core. The service core includes basic building's functional elements such as passenger and service lifts, stairs, mechanical and electrical risers, distribution and equipment rooms and lavatories. Subject to the specified statutory constraints, the lettable to gross floor ratio of a building can be optimised by maximising the size of the floor plate to increase its lettable floor area and minimising the size of service core to an acceptable level. It is noted that the site areas of the sampled buildings are relatively large due to its prestige nature and as such, the design of the floor plate may not be constrained by the maximum site coverage. As noted from Table 2, the floor plate of the studied buildings is comparatively large, ranging from approximately 2,100m^2 to 2,800m^2 (in the typical floor). All these buildings can achieve a high lettable to gross floor ratio of about 80%.

	Building	Floor Plate Size (m^2)	Lease Span (m)	Floor Height (m)	Wall to floor ratio	Floor to Ceiling (m)
1.	Taipei 101 Tower	2650	9.8 - 13.9	4.2	0.33	2.80
2.	Petronas Tower 1	2150	8.3 - 13	4.0	0.40	2.65
3	Petronas Tower 2	2150	8.3 - 13	4.0	0.40	2.65
4	Jin Mao Tower	2600	11.8 - 14.8	4.0	0.30	2.79
5.	2 International Finance Centre	2800	14.5	4.0	0.32	2.70
6.	CITIC Plaza	2230	11.3	3.9	0.33	2.70
7.	Shun Hing Square	2160	12 - 12.5	3.75	0.33	2.65
8.	Central Plaza	2210	9.4 - 13.5	3.9	0.34	2.60
9.	Bank of China Tower*	2704	17.6	4.0	0.31	2.80
10.	The Center	2100	12.0	3.725	0.36	2.60

Table 2: Summarised Data of Sampled Buildings

*Note: In the Bank of China Tower, the data is based on the lower floor only.

Since the external wall is a cost significant element, any reduction in the external wall will gain reduction in the unit cost. The proportion of external wall area decreases as the size of the floor plate increases. For a given size, a larger floor plate will result in a lower wall to floor area ratio. As noted from Table 2, the average wall to floor area ratio is 0.34. The Jin Mao Tower has the lowest wall to floor area ratio of 0.30, whereas the Petronas Towers have the highest wall to floor area ratio of 0.40 is due to its relative smaller floor plate and irregular external outline. If the Petronas Towers are excluded, the average wall to floor area ratio will become 0.33 which can be considered to be low.

4.2 Lease Span

Lease span is the clear distance from the building core to the external wall. It depends upon the functional requirement and size of floor plate. Based on the collected data, the most common lease span is approximately 12m, ranging from 9.80m to 13.89m. The Bank of China Tower has the longest lease span of approximately 17m at its lower floors due to its split core design.

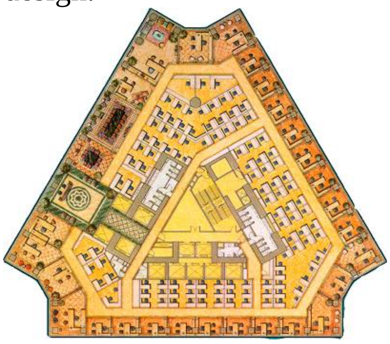


Figure 1: Typical Layout Plan of Central Plaza

When considering flexibility of office planning, it is desirable to have as few columns as possible within the lease span area. A column free floor from window wall to building core is an optimum solution for office development. As shown in Figure 2 later, except the Central Plaza, all sampled buildings have no columns between its building core and exterior window, thus allowing maximum flexibility in interior planning. In the Central Plaza there is only one column at the middle. This does not significantly affect its internal layout.

4.3 Floor Height

The floor height consists of two aspects; namely, the floor-to-floor height and floor-to-ceiling height. The minimum floor height may be determined by the relevant building regulations. As shown in Table 2, the floor-to-ceiling height ranges from 2.60m to 2.80m with an average of 2.69m. The difference between the lowest and highest ceiling height is only 200mm.

The difference between floor-to-floor height and floor-to-ceiling height is the space for accommodating the horizontal mechanical and electrical services within the ceiling void and the structural floor system. Raised floor is provided in some buildings (such as the Taipei 101 Tower, Petronas Towers and 2 International Finance Centre). This provision increases the floor-to-floor height, while keeping the floor-to-ceiling height. The overall floor height has an impact on the overall economics of a building since a small increase in floor height can have a great effect on all vertical elements of a building. The design of floor height can be optimised by minimising the overall floor height, while maintaining the floor-to-ceiling to an acceptable minimum. According to the collected data, the most common floor-to-floor height is 4.0m, ranging from 3.73m to 4.20m.

The structural floor system can have an impact on the overall floor height. Traditional concrete beam and slab flooring system is adopted in the CITIC Plaza and Central Plaza, whereas steel flange beam with composite metal deck and concrete flooring system is adopted in the remaining sampled buildings. One may expect that the concrete flooring system is normally deeper than the steel flooring system and should have a higher overall floor height. However, it is found that there can be no direct relation between the structural floor system and its overall floor height because it is also depended on the design of the ceiling height.

4.4 Plan Shape of Building

The geometry of the floor plan has significantly impact upon the interior space planning, exterior building envelope and structural system. Generally the simpler and more regular the floor shape, the more easily it can be adapted to the user's needs in terms of space planning. Square and rectangular floor plans work more efficiently than curved and irregular shapes.

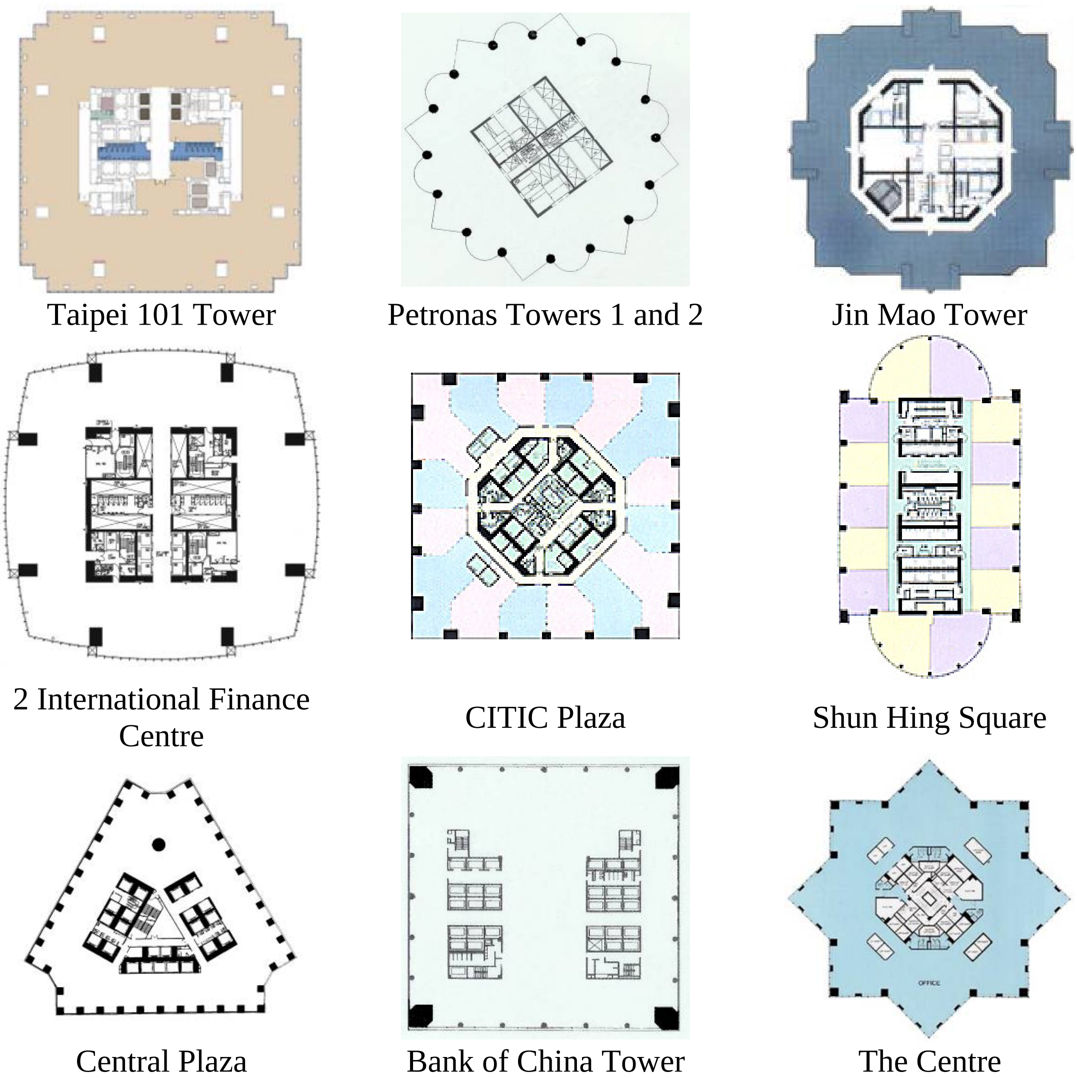


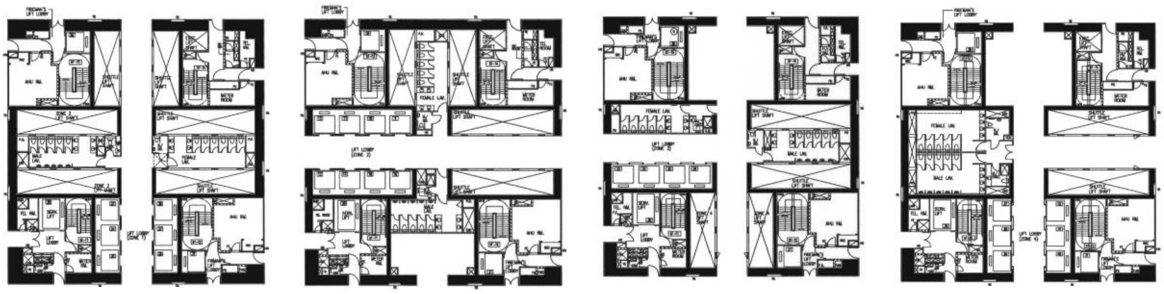
Figure 2: Geometry of Typical Floor Plans of Super Tall Buildings

Symmetrical plan buildings are less susceptible to lateral wind impact than unsymmetrical buildings. This is particularly important in super tall buildings. As shown in Figure 2, there is a tendency of having square plan in order to achieve planning and structural efficiency. Since square geometry offers the same stiffness in both directions against lateral wind forces, square or similar plan is the most common geometry in super tall buildings as illustrated by the Taipei 101 Tower, Jin Mao Tower, 2 International Finance Tower, CITIC Plaza and lower floors of the Bank of China Tower. The triangular floor plan can be illustrated by the Central Plaza. The Petronas Towers, Shun Hing Square and Centre are examples of hybrid shapes. Although the plan shapes of the Petronas Towers and Centre are not regular, their layouts are symmetrical about both axes as the square plan and are therefore able to achieve similar planning and structural efficiency.

4.5 Service Core

A service core is those parts of a building consisting of the lift shafts, lift lobbies, staircases, toilets, mechanical and electrical systems, riser-ducts and plant rooms. The design of a service core can significantly affect the overall space efficiency of the building, vertical circulation system and distribution routes of mechanical and electrical system. In many tall buildings the core structure also acts, either in isolation or in conjunction with the perimeter frame, as the principal load bearing element for both the gravity and wind loadings.

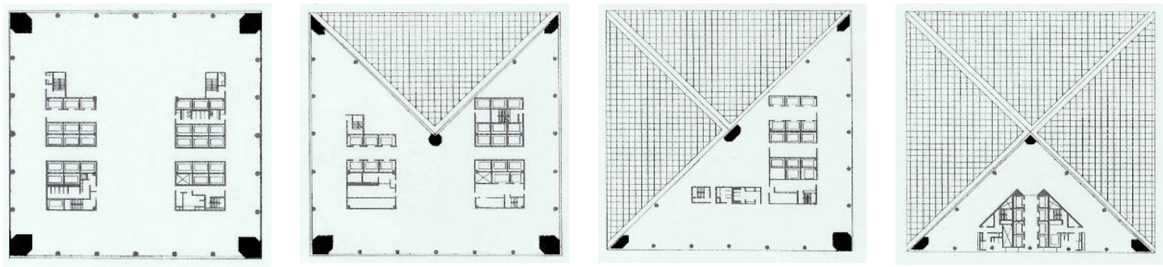
In order to achieve an economic layout for a building, the size of its service core should be reduced to an acceptable minimum, while meeting the fire regulations on fire routes and staircases, achieving an effective vertical transportation and creating an efficient internal layout. There are three generic approaches to designing a service core; namely, central core, split core and end core. It is found that the central core approach is used in all sampled buildings, except the Bank of China Tower which adopts the split core approach. The central core is designed as a structural element to provide stability for the building. Within the central core, its internal layout is changed because of the changing vertical lift transportation systems at various levels as exemplified in Figure 3. The thickness of the core wall is also gradually reduced at higher floors.



Levels 8 - 18 Levels 19 - 32 Levels 36 - 42 Levels 47 - 52

Figure 3: Service Core Layouts of 2 International Finance Centre

The Bank of China Tower is based on a cross-braced space truss structural system. The design of the service core is not part of the structure and can thus be more flexible as shown in Figure 4. However, its design is also limited by the vertical transportation system, building layout and form as well as other functional requirements.



Levels 6 - 16 Levels 26 - 31 Levels 38 - 44 Levels 51 - 66

Figure 4: Service Core Layouts of Bank of China Tower

The structural core material can be built from steel or concrete or both. For a tall building, if the service core wall is built in concrete, its structural weight can be very heavy, thus inducing an additional cost for the foundation. In the United Kingdom and America, steel is commonly used as the structural element and lightweight fire-rated drywall is used to form the service core walls in order to reduce its thickness and save the foundation cost and construction time. In Asia Pacific countries, however, the use of structural steel and drywall construction is generally less common because their costs are higher than reinforced concrete construction. With the advent of concrete technology, high-strength concrete (over 100 MPa) can be used to reduce the thickness of service core walls, thus maximizing the useable floor space. Fire rating for lift shafts and stairwells can also be easily achievable by designing the concrete core walls to specified thicknesses. Service core construction typically lies on the critical path of the programme and thus affects the project completion date. By using slip-form or jump-form techniques, a 3 to 4-day cycle is achievable for core wall construction. This construction speed is similar to steel construction. In other word, concrete construction is not slower than the steel construction.

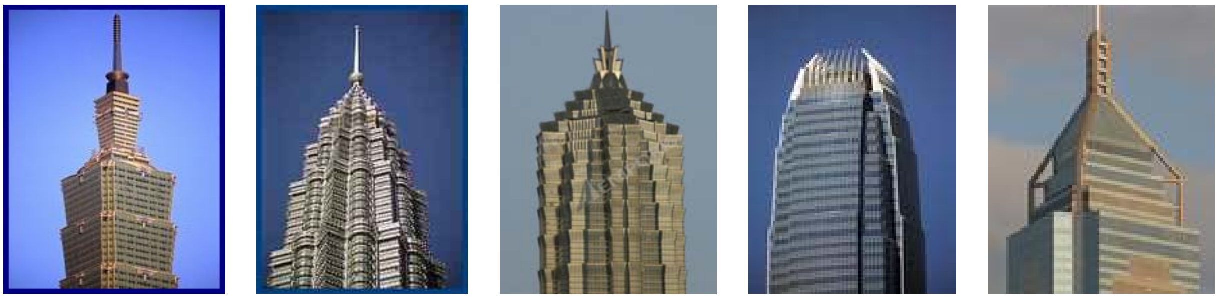
4.6 Building Form

The form of a tall building has a major impact on the building aesthetic and behaviour. While the building form is determined by its functional requirements, super tall building is highly susceptible to the wind load which is a major design criterion. The building dynamic response to wind force can be controlled by varying the shape along its height both in plan and elevation. Figure 5 shows the forms of the sampled buildings.

Taipei 101 | Petronas Towers | Jin Mao Tower | International Finance Centre | CITIC Plaza | Shun Hing Square | Central Plaza | Bank of China | The Centre

Figure 5: Form of Super Tall Buildings in Asia Pacific Countries
Building Diagrams adapted from Emporis Building

Based on the above building forms, there are three general observations at its lower (podium) floors, main tower and top floors. Firstly, there is a large podium floors at lower levels (including basement floors) which are to accommodate the separate commercial and retail functions. Secondly, there is a setback in the overall floor plan dimension in the main tower which is to accommodate different functions. The setback causes the main tower to be smaller than the lower floors to meet the structural needs for wind resistance and functional requirements for different users. It is also observed from the elevation of the main tower that there is no much variance of window size and proportion due to different floor-to-floor heights, except at the lobby and mechanical floor. They utilize a single structural system and a single construction material. Thirdly, since tapering has a significant improvement in the overall building structural behaviours to wind force, many buildings have a slightly tapered building shape at its top floors. This includes the Taipei 101, Petronas Towers, Jin Mao Tower, 2 International Finance Centre and Central Plaza as shown in Figure 6.



Taipei 101 | Petronas Towers | Jin Mao Tower | 2 International Finance Centre | Central Plaza

Figure 6: Tapered Shape Buildings

4.7 Structural Systems

The structural system has a great impact not only on exterior aesthetics of a building, but also on its interior space planning. Thus, it must be considered with its structural material, functional requirements, and building shape and form (such as the location of columns and bracing, the relationship of columns to the planning grid and the size of the service core).

In addition to its dead and imposed loads, a super tall building must be designed for resisting horizontal wind or seismic loads, whichever is greater. For a building located in a seismic area, even when wind forces govern the design, structural connections must also be designed to absorb seismic energy. Table 3 summarizes the structural systems of Asia Pacific's 10 tallest buildings.

Building	Height	Floors	Structural System
Taipei 101	509 m	101	The structural system primarily comprises eight 3 x 2.4m steel box section mega-columns filled with reinforced concrete up to level 62. Main floor girders connect each mega-column with a core corner column, forming a tick-tack-toe board. The square-shaped core comprises 16 box section columns, which are fully braced between floors. Outriggers connect mega-columns and the core at every eighth level.
Petronas Towers	452 m	88	The structural system comprises high-strength reinforced concrete perimeter columns and ring beams which are tied with a reinforced concrete central core by a 2-storey deep outrigger truss. Typical floor system consists of wide flange beams spanning from the core to the ring beams with a composite metal deck with concrete topping.
Jin Mao Tower	421 m	88	The structural system primarily comprises eight perimeter composite mega-columns encased with concrete. The mega-columns are linked to an octagon-shaped reinforced concrete core by steel outrigger trusses at three levels and capped with a 3-dimensional steel space frame at the top level. The floor system comprises composite wide flange beams with a composite metal deck with concrete topping floor slab.
International Finance Centre	415 m	88	The structural system primarily comprises eight perimeter composite mega-columns which are encased with concrete and linked to a square-shaped reinforced concrete core by steel outrigger trusses at four levels.

CITIC Plaza	391 m	80	The structural system is based on a tube-in-tube system comprising twenty high-strength reinforced concrete perimeter columns and floor edge beams and an octagon-shaped reinforced concrete central core. The beams and floor slabs connect the perimeter columns and central core.
Shun Hing Square	384 m	69	The structural system primarily comprises a peripheral rigid steel frame and reinforced concrete rectangular central core which are connected by rigid steel outriggers at four levels. The floor plates comprise closely-spaced steel beams and one-way spanning slabs.
Central Plaza	374 m	78	The structural system is a tube-in-tube system comprising high-strength reinforced concrete perimeter columns at 4.6m centres and 1.1m deep floor edge beam and a triangular-shaped reinforced concrete shear-wall core.
Bank of China Tower	367 m	70	The structural system is a cross-braced space truss system comprising four concrete encased composite steel mega-columns at building corners and one column at centre to resist both lateral loads and almost the entire weight of the building.
The Center	346 m	73	The structural system primarily comprises twelve steel box section mega-columns and steel outrigger trusses at three levels. The columns are filled with concrete for 20 storeys, then reduce in size and become hollow as they reach the top.

Table 3: Structural Systems of Asia Pacific's 10 Tallest Buildings

As shown above, the two commonly used structural systems for super tall buildings are composite mega-columns with central core and outriggers system (such as the Taipei 101, Jin Mao Tower and 2 International Finance Centre), and reinforced concrete tube-in-tube with or without outriggers system such (as the Petronas Towers, CITIC Plaza and Central Plaza). It is technically feasible to utilize composite mega-columns with central core and outriggers system to achieve the 509m high, 101-storey world's tallest Taipei 101 Tower, and reinforced concrete tube-in-tube with outriggers system to achieve the 454m high, 88-storey world's second tallest Petronas Towers. In other word, there is no technical difficult to use either steel or concrete structures for the construction of super tall buildings.

The selection of construction material may be dependent on building height and functions. Each construction material has certain limitations in terms of its physical properties and economical feasibility. Steel has been commonly used as the main structural material for tall buildings such as the 442m high Sears Tower and 381m high Empire State Building in America. In many Asia Pacific countries, however, there are limited supply of quality structural steel and experienced contractors in steel fabrication from their local markets. Steel construction is more expensive than reinforced concrete solution, when taking account of the additional fire protection cost for structural steel members. With the development of advanced material technology, very high-strength concrete (over 100MPa) can be produced with no great difficult from materials easily available from local market. Thus the use of high-strength concrete is commonly used in Asia Pacific countries except Japan and Korea.

The total structural material quantity and its cost have always been an important determinant for development of super tall buildings. The structural efficiency can be measured by means of the lowest total cost solution which may be optimised by (1) minimising the total structural cost by using locally available materials and labourers where possible, (2) minimising the sizes of structural members so as to increase the usable/rentable floor area and thus its future revenue, (3) minimising the structural weight so as to reduce its impact on the foundation, and (4) minimising the overall construction time so as to generate income earlier and also reduce the finance cost.

4.8 Vertical Transportation System

A tall building requires an efficient vertical transportation system typically comprising passenger lifts, service lifts and fireman lifts. The number of passenger lifts is generally determined by the population of the building, type of building occupancy, population during peak period, number of floors and heights, and building location in relation to public transport services. More specifically it depends on the quality of service, round-trip time, flow rate, interval for lifts, lift travel and lift speeds. Generally when the building becomes taller, additional lifts are required to accommodate the additional population. The lift arrangement has a major impact on the size and internal layout of the service core which, in turn, affects the net rentable floor area. Therefore an economic design should aim at striking a proper balance between the passenger handling capability and rentable floor space.

For a tall building, the vertical transportation system is usually based on the multi-zone system in which the building is divided into a number of lift zones such as low, mid and high zones. Prospective passengers take lifts at the main lift lobby to reach a destination floor. However, for a super tall building, the size of the service core becomes excessively large. In order to keep the service core within a reasonable size while maintaining an acceptable level of response time, the sky-lobby system may be adopted as a solution. Passengers take shuttle lifts to the sky-lobby and then transfer to other lifts to higher floors. An example of this system is the 78-storey Central Plaza in Hong Kong in which the vertical passenger transportation system is divided into lower floors (below sky-lobby) and upper floors (above sky-lobby). The lower floors are divided into four lift zones and are served by totally sixteen lifts (i.e. four lifts per zone). The upper floors are divided into three lift zones and are served by totally twelve lifts. Five shuttle lifts transport passengers between the main lift lobby and sky-lobby at 46/F. When compared with the multi-zone system, seven lift shafts at the lower floors are saved. The 69-storey Shun Hing Square in Shenzhen also adopts the same multi-zone, sky-lobby system.

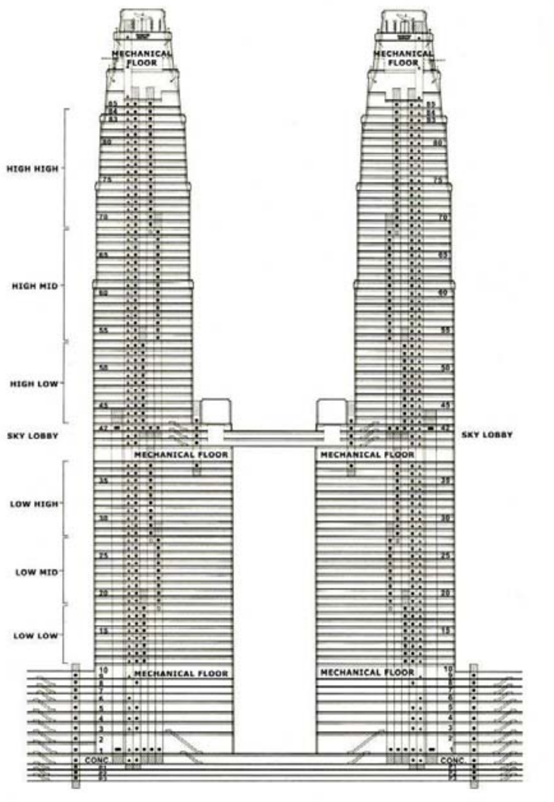


Figure 7: Lift Zoning Schematic Diagram of Petronas Towers
Adapted from Pelli and Crosbie (2001:40) with modification

Another solution to keep the service core within a reasonable size is the double-deck lift system. Two lift cabs are stacked vertically in a common lift frame and thus increase the passenger handling capacity. When compared with the conventional lift system, this significantly reduces the number of lift shafts, but new users may find this system confusing unless there are adequate directional signages. In addition, it may also be used with the sky-lobby system to further reduce lift shafts at the lower floors. The best example of this system is the 88-storey Petronas Towers 1 and 2 in Kuala Lumpur in which the vertical passenger transportation system is divided into lower floors (floors 8 – 37) and upper floors (floors 44 - 83) with sky-lobbies at floors 41 and 42. Within both the lower and upper floors, it is further divided into low, mid and high lift zones. Lower and upper floors are each served by twelve double-deck lifts and sky lobbies are served by five double-deck shuttle lifts. The double-deck, sky-lobby system is also adopted in the 101-storey Taipei 101 Tower in Taipei and 2 International Finance Centre in Hong Kong.

In many Asia Pacific cities, the passenger lift is not considered as a means of escape in case of fire and thus a fireman’s lift is required to serve all usable floors. In addition, a building also normally requires one or more service lift for transportation of goods to various floors. In order to reduce the number of lift shaft, one of the service lifts is often designed for dual-use as a fireman/service lift.

5. CONCLUSIONS

The structural system is the most important criterion for the development of super tall building as it inter-relates with the plan shape, floor plate, lease span, floor height, building form, service core and vertical transportation. With sufficient site area, the building can be designed to have a larger floor plate to achieve a higher lettable to gross floor ratio, and a longer lease span to allow a greater flexibility in interior space planning. Since square geometry offers the same stiffness in both directions against lateral wind forces, square or similar plan is the most common geometry in super tall buildings. Because the service core is designed as a structural element to provide stability for the building, central core approach is commonly used in super tall buildings.

The two commonly used structural systems for super tall buildings are composite mega-columns with central core and outriggers system and reinforced concrete tube-in-tube with or without outriggers system such. Either steel or concrete structures can be used for super tall buildings, but high-strength concrete is more common due to its lower cost compared with steel.

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BIOGRAPHICAL NOTES

Dr. Ho is currently the Associate Head of the Division of Building Science and Technology, City University of Hong Kong. He is a quantity surveyor by profession. Before joining the City University, he has been worked as a project manager with leading property developers for over ten years. His extensive experience in the property and construction industry, especially as the project manager, covers the whole property development process from initial technical and financial feasible study, management of architectural, structural and building services engineering designs, cost planning and control, tender documentation, construction to facilities management.

He is an active researcher and has published a large number of research papers. His current research interests include property development, project/construction management, construction economic and contractual matters. In addition, he has also enthusiastically contributed to the relevant professional institutions and the community. In particular, he served as the Chairman, Quantity Surveying Division, The Hong Kong Institution of Surveyors in 2005-06.

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