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Cost Planning and Control

成本规划与控制

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This chapter looks at the major cost drivers of tall buildings such as the overall design planning, foundation and substructure, structure, façade, architectural works, interior fitting out, elevator provision, building services, etc. With advanced construction technology and land scarcity, the authors view is that, where there is a financially-justifiable business case, buildings will go higher, but there are hurdles, such as government regulations and environmental issues. to overcome. As demonstrated in the Ping An case, it relies on establishing a realistic overall budget through understanding of the common features of tall buildings, all the efforts in tracking the development of the designs, offering cost advice and cost comparisons for various design options to make it successful.

我们探究了高层建筑中经费支出的主要方向，比如: 总体的设计方案、基础、地下结构、结构、立面、建筑设计工作、内部装修、电梯预算，物业服务等。在先进的建造技术与土地匮乏现状的驱使下，我们相信，只要所需预算在商业前提下是合理的，建筑将会越建越高，但是这种设想也会遇到障碍，如政府规范，环境问题等等需要克服的因素。以平安国际金融大厦为例，整个项目的成功依赖于基于对高层建筑一般规律的了解而建立的合理总预算、全程追踪设计进度所付出的努力、以及对多种设计方向所需成本的评估及合理选择。

Introduction

A "tall building," citing CTBUH's criteria, "does not have an absolute definition" and "it is a building that exhibits some element of tallness." In the context of this chapter, the authors regard tall buildings as those over 200 meters tall and 50 stories or more.

Tall buildings are not just the aspiration of architects or engineers; they are also popular with developers. The following are seen as the commercial advantages brought about by the tallness of buildings :

- Only a small amount of land area is needed in exchange for a large amount of floor spaces and real estate values, which is particularly desirable in those already fully developed and prominent CBD areas in which land supply is limited
- Tall buildings as iconic landmarks provide an excellent marketing image for the developer
- With their prominent location, unobstructed and panoramic view of the city allowed by its height, and the quality working environment brought about by high-end interior design and finishes and building services systems, tall buildings are generally more attractive to top-tier customers like financial institutions

With such height and large number of floors, and sometimes with different floor zones designated for different functional uses like offices and hotels, tall buildings are inevitably large in scale and complex in nature, and represent a major investment in most cases. Moreover, contrary to the general perception that there would be economy of scale, the construction cost per square meter of floor area of a tall building tends to increase as the number of stories increases, and it is important for developers to have proper cost planning for, and control of, the same.

前言

高层建筑，按CTBUH的标准，"没有一个绝对的定义"而是"展現出一些高层元素的一个建筑物"。作為这篇论文的背景，我们定义為那些50 层以上及超过200米高的建筑物為高层建筑。

高层建筑并非仅属于建筑师或工程师的夢想，对发展商來说他们也極具吸引力。以下被视为建筑物的高度所能带来的商业优势:

- 发展商只需少量的土地面积，便可换取大量的地面空间和房地产价值。对于已被充分发展而出現一地難求的CBD地区來说，是十分重要的 。
- 高层建筑作為标志性建筑，可提供予发展商一个最好的市场形象
- 高层建筑一般处于市內优越的位置，其高度則可提供無遮擋的城市全景，加上高端室內设计装饰和服务系统，所營造出的工作环境对一些顶级客户如金融机构將更具吸引力

不論按高度或总体建筑面积來看，高层建筑都屬於大规模的建筑体量，而在很多情況下，不同的楼层区被设计為不同功能用

Figure 2.12. The Ping An Finance Center being constructed within the Shenzhen skyline (Source: Ping An)
图 2.12 深圳天际线中的平安金融中心的施工场景 (来源: 平安)

Cost Planning

The cost planning and control process involved the following:

1. Establishing of an overall construction budget based on known design parameters together with the Client's intended quality/standard of the project. Such overall construction budget would be established at the end of each stage of design and in line with the design team's deliverables for each stage, i.e., the concept design, the preliminary design, the detailed design, and the tender drawings stages.
2. Continual tracking of the design development of different elements and components at each respective stage of the design process.
3. Identify any element or component where, in the course of design development, the intended design or choice of materials or technology is found to be different from the

途，如办公室，酒店等，则构成其建造上的复杂性。因此，在大多数情况下，高层建筑都代表了一个相应龐大的投资。而有别于一般看法的，则是高层建筑往往不具备规模经济，其单方建筑成本会隨著楼层数量的增加而上升。 因此，对发展商來说，适当的成本规划和控制就有其重要性。

平安金融中心的成本规划和控制

成本规划与控制包括以下步骤:

1. 根据已知设计参数，例如可建面积，可建高度限制等，結合业主方对项目要求的质量/标准，并按照设计团队在设计的不同阶段即概念设计，初步设计，扩初设计和招投标图或施工图阶段所編制的图纸及其它的資料，制订出項目于不同阶段的整体建筑成本估算。
2. 在设计过程的不同阶段，持续追踪不同的建筑元素和组件的设计开发。
3. 在追踪不同的建筑元素和组件的设计开发过程中，确定所有與原有的假设不同而且会对整体建筑成本有显著影响任何的设计，或选择的材料，或所採用的技术。
4. 联络客户和设计团队，探索这些建筑元件进行价值工程的可能性，以及研究在楼宇设备中设计、材料和系统之间的各种可行方案。 在这些情况下，我们主要為不同的方案提供成本研究/比较，以便客户和设计小组进行审议和决策。
5. 在第 (4) 项經优选的各个方案将被纳入到整体工程预算，使得客户在设计过程的每个阶段，都能夠有一个清晰的成本监测和控制的目标。

在下文中，我将介绍一些高层建筑的特点，而这些特点是和其建筑成本有关的，以及我们在平安中心項目所作出和这些特点有关的成本调研案例。

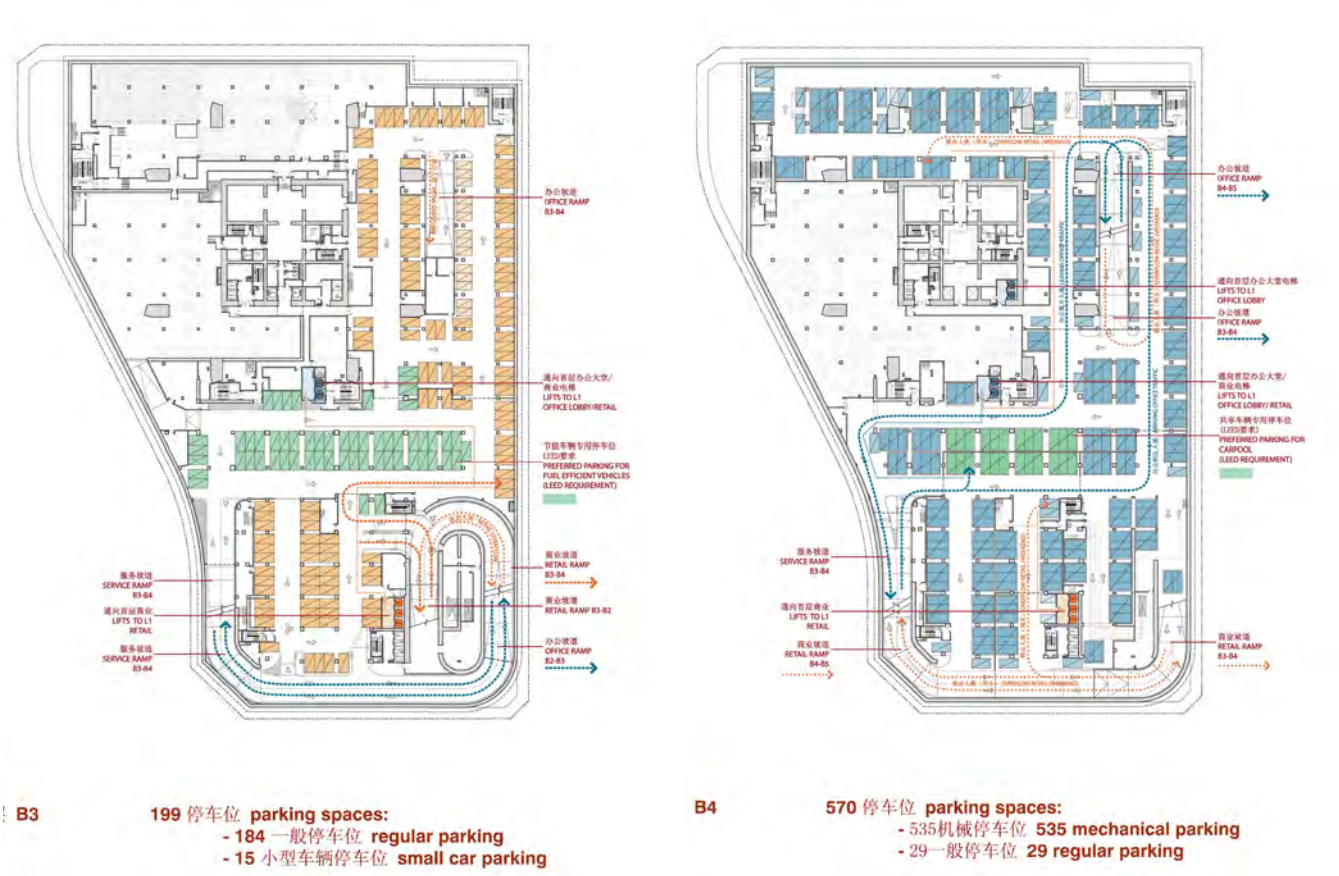

Figure 2.13. Parking plans for basement levels three and four (Source: Ping An)
图 2.13 地下3、4层的停车场平面（来源: 平安）

original assumption upon which the overall construction budget was based, and would have a significant impact on the overall construction budget.

4. Liaise with the Client and the design team to explore the possibility of value engineering, and to study and consider various options of designs or choice of materials or systems in the case of building services. In these cases it is necessary to provide cost studies/comparisons amongst different options for the Client and the design team's consideration and decision making.
5. The outcome of (4) above would then be incorporated into the overall construction budget, such that the Client would have a clear target for the purpose of cost monitoring and control at every stage of the project.

In the following pages are discussed some cost-significant features of tall buildings, and exemplified by the various cost studies cases that were executed in the case of Ping An.

Planning

The following are some common architectural planning features that were observed from the tall building projects in which the authors have been involved.

Tall buildings are usually located in prominent sites or central business districts (CBDs) of a city. Apart from the ground-floor level, which usually is used as the main reception / circulation area, the podium levels and even one or two levels of basement at these locations are usually very valuable and attract a high selling price or rent. Therefore, unless there are ample parking facilities nearby, a tall building tends to have deep basements, with the lowest few basement floors used as car parks. For Ping An, a total of 5 stories of basement is being constructed, with Basement 1 being Retail and Basement 2 to 5 as Loading/Unloading and car parks (see Figure 2.13).

建筑规划

以下是我们观察到高层建筑的一些常见的建筑规划特点。

高层建筑通常位于一个城市的商业中心区(CBD)。 除了地面层通常被用来作为主接待层外，其裙楼以至地下一层或地下二层仍然是極具商业价值的，能吸引到較高的售价或租金。 因此，除非其所在地附近有充足的停车设施，高层建筑往往亦设有多层地下室並把最低的几层作为停车场。以平安中心來说，其一共有五层地下室，地下一层为零售而地下二层至五层則为装货/卸貨区及停车场 (见图2.13) 。

為符合有关消防安全法规或当地的消防规范，高层建筑通常设有避难层，提供不同的楼层区域之间的防火分隔。平安中心來说，則总计有八个避难层。

不同于一般的建筑物，把建筑设备的主要设备如冷却塔等，放置于裙楼顶或天台，对高层建筑來说，机电系统的主要设备的总空间需求，加上相关管道系统所佔用的空间，都令致其不能在单一的楼层上所能容納，而需要分开配置于几个机电层，並且由每个机电层的设备去满足部分功能区域楼层的机电需求。 这些机电层

To cope with the relevant fire safety requirements / local fire codes, tall buildings usually have refuge floors to provide fire separation between different floor zones. For Ping An, a total of eight refuge floors have been provided.

Unlike normal buildings, where the building services main plant such as cooling towers are either located on the podium roof or rooftop, in tall buildings the total space requirement and also the long distance of circulation ductworks and pipeworks renders it impractical to locate services on one single floor to serve the whole building. Rather they will be found in several MEP floors, each serving a particular zone of functional floors. These MEP floors also need to be of higher story height than normal functional floors in order to allow the building services main plant to function properly and for transfer of pipeworks. The floor loading requirement may also be higher than for normal functional floors.

The refuge and MEP floors are usually non-accountable in gross floor area (GFA) calculations. Therefore, we have to be careful in the very initial stage of the project, when high-level budget estimates have to be prepared without drawings and must be based on floor areas as indicated in the land lease, to make allowances for these extra floors.

To cater to the long vertical travelling distance, some tall buildings are designed to have multi-zone elevator systems, with each zone served by different groups of elevators. A shuttle elevator system will also be adopted, taking the passengers to intermediate zones for transfer to the top zone, and therefore additional "sky lobby floors" will be provided to allow passengers to be transferred among different zones (see Figure 2.14).

The relatively deep basement and numerous floor layouts imply a longer construction period for tall buildings, which leads to both an increase in construction costs and risks. These costs and risks must be contemplated at the beginning and controlled until completion.

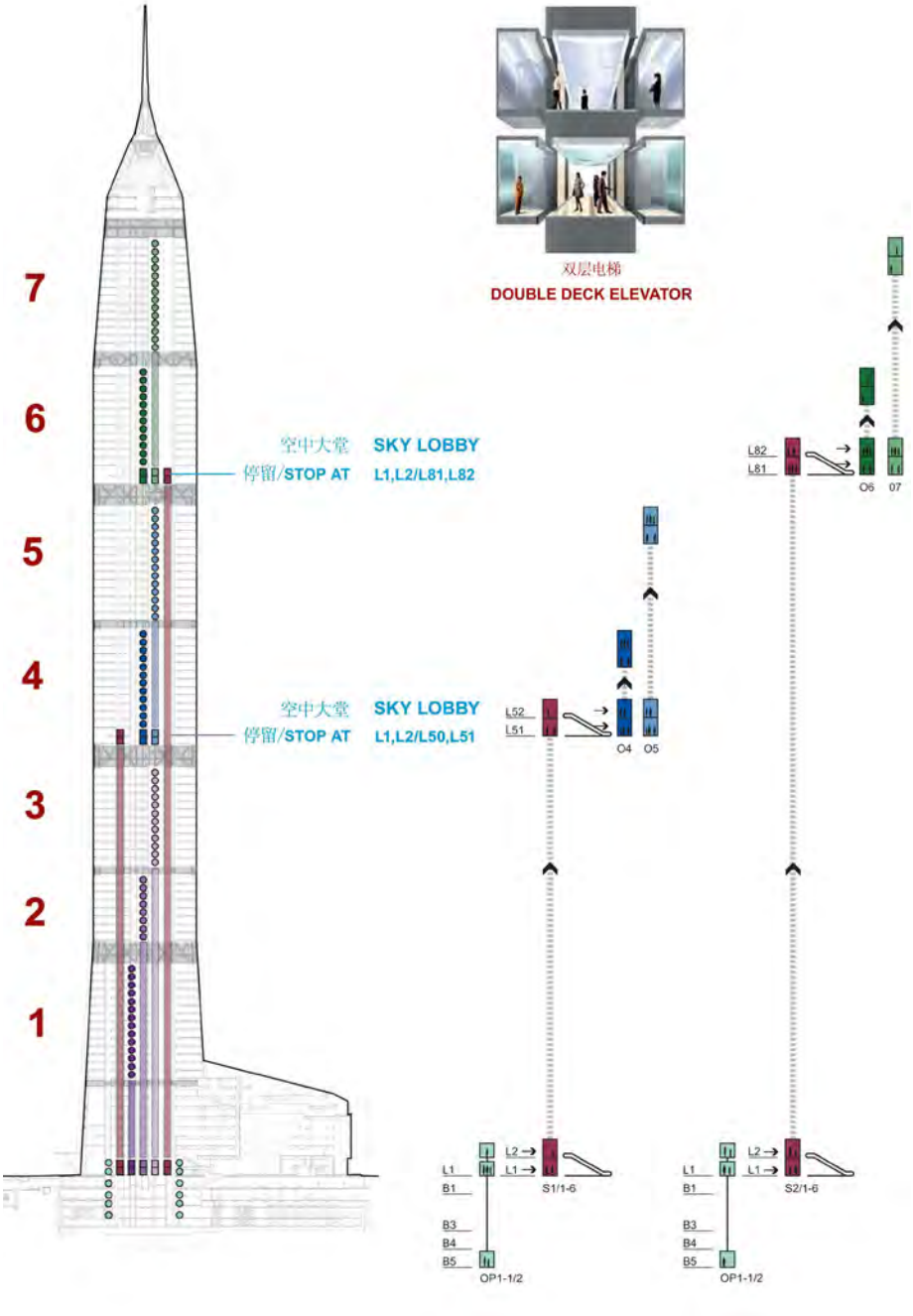

Figure 2.14. Elevator plan and the "sky lobby floors" (Source: Ping An)
图 2.14 电梯方案与空中大厅层 (来源: 平安)

一般需要比正常的功能层較高的楼层高度，以便机电设备的正常运作和管道转移。而机电层的承重要求亦比正常的功能层更高。

避难层和机电层通常都不计算于按容积率计算的可建楼面面积 (GFA) 之內。 因此，在一个項目的初始階段，图纸的编制尚未开展期間，我們对客戶所提供的，基于可建楼面面积的初步预算時，必须仔细考慮並算入这些额外的楼层的成本。

考慮到高层建筑內，垂直運輸的路程遥远，一些高层建筑的设计具有多区电梯系统。而穿梭电梯系统的采用，可以把乘客了由中层区迅速转移到顶层区，而因此高层建筑內亦出現额外的"空中大堂"楼层，提供不同区域之间乘客转移共用之平台 (见图2.14) 。

高层建筑比较深的地下室和众多不同的楼层布局亦意味着较长的建设周期，导致建筑成本和风险的增加。 这些成本和风险，必须在項目开展階段已加以考虑並且需在整个建设期加以监控，直到項目完成为止。

Figure 2.15. Construction process of the piles (Source: Ping An)
图 2.15 桩施工过程 (来源: 平安)

Foundations and Substructure

Tall buildings are usually designed to rest on bedrock with end-bearing piles (see Figure 2.15). Theoretically, the taller they are, the lower the per-square-meter foundation costs will be. However, if the bedrock level is too deep or not suitable for end-bearing, the pile lengths may increase with the height of the building to account for the overturning moment of the buildings, the wind load imposed on the top sections of the buildings, and the provisions against seismic load. These will all drive up the foundation costs.

As mentioned above, most tall buildings have deep basements (see Figure 2.16). The construction of deep basements and deep foundations using conventional approaches usually takes a long time. Very often an alternative methodology or construction sequence, to save overall construction time, like top-down construction, will be considered. Such alternative methodologies, however, would increase the complexity of construction. In addition, if the tall building is located near a public transportation / underground subway hub, which is not uncommon for prominent CBD sites, one would also expect very stringent control and restrictions on construction activities so as to prevent possible disturbance to public facilities and neighbors, many monitoring and precautionary measures will also be imposed. The difficulty of construction will be even greater, and so will be the construction cost of the deep basement and foundation.

The design and method of construction of the deep basement and foundation thus deserves careful planning and study in order to arrive at the optimum solution in terms of time and cost.

Structure

Tall building's structure has to overcome heavy wind loads and/or meet seismic design requirements, while being efficient enough not to affect the layout / planning of the functional floors. Structure is always a very significant element of a tall building.

基础和地下结构

高层建筑的地基设计通常为桩基並且桩底直接承載于地底岩层上 (见图2.15) 。理论上，建筑层数越多，其基础的每单位成本将越低。但如果地底岩层过深或不适合桩底直接承載，而桩基需按摩擦桩设计，则桩的长度將会按建筑物的高度增加，以抵禦施加在高层建筑物的倾覆力、在建筑物的顶部部分的风荷载、以及地震的抗力，如此則基础成本將按建筑层数增多。

如上面所提到，大多数高层建筑亦有很深的地下室 (见图2.16) 。如采用常规方法即地面大开挖方式去建造这类深层地下室及大深度的基础，通常需要較长的时间。很多的時候，发展商或设计团隊都会考慮替代方法或施工方案，像自上而下的施工方案，以节省整体施工时间。但这样的替代施工方案会增加施工的复杂性。此外，对位于一个城市的商业中心区(CBD)的高层建筑來说，很大可能是其附近会有一个公共交通/地下铁路枢纽。為了防止高层建筑的基礎或地下室的施工可能干扰到上述公共/地下铁路枢纽的運作，政府也会对有关的建筑活动作出非常严格的的限制和要求大量的监测和预防措施。因此，深层地下室和地基建造的难度会更大，而其建设成本亦变得更高。

对高层建筑來说，深层地下室和地基的设计与施工因而值得认真规划和研究，以尋找出在时间和成本方面上取得最佳平衡的方案。

结构

高层建筑的结构必须满足自身載重，风荷载和/或抗震的设计要求，但另一方面必须是有效率而不影响功能楼层的布局/规划。它並且是高层建筑的一个非常显著的元件。

高层建筑结构的设计，不仅是考虑结构本身的成本高低和施工所需時間的長短，对于结构尺寸以至所占据了楼面面积比例的多少，以及其是否阻挡了建筑物的景觀等，也是设计考虑的因素。

综合了上述这些因素的考慮，当今高层建筑的结构设计大部分都採用綜合的结构系统，如钢筋混凝土核心筒，钢结构框架或型钢结构框架，预应力的楼板和/或樑，和钢结构桁架，以减少垂直结构元件的尺寸並最大化提升楼面使用面积的效率。

One must consider not only the time and cost of the structure itself. For tall buildings, one must also consider the proportion of a floor occupied by the structure, and whether the structural components like peripheral columns or cross-bracing would obstruct the prestige views from the building.

As a result of these considerations, it is almost the norm today that a tall building structure will be designed as a combination of structural systems such as reinforced concrete core wall, structural steel frame or composite frame, prestressed works and trusses to reduce the sizes of the vertical structural elements and maximize the efficiency in usable floor area. Such a combination invariably results in higher structural costs than conventional reinforced concrete structure. In addition, the physical constraints during construction, i.e., the longer travelling time for vertical transportation of materials and labor, the increased difficulty of working at high levels etc., also contribute to the high cost of the structure.

The sheer scale of the structure makes it an element for which it is worth studying and comparing different options. The following are some of the cost studies /comparisons that were carried out on Ping An:

- Vierendeel vs belt truss scheme
- Reinforced concrete vs composite reinforced concrete / steel structure scheme for podium floors
- Typical floor framing with and without built-up beams
- Typical floor slab with and without profile steel decking

The final selection in the above had not been on their order of costs, but on other aspects, such as the comparative speed of construction, the advantage of smaller member sizes, etc.

Façade

In addition to being the envelope of the building and its main defense against high wind impact, the façade is also the most

这样的结构组合比传统的钢筋混凝土结构的建造成本更高。 此外，高层建筑施工过程中的限制，即垂直運输物料和劳工需時較長，高空工作难度及危險度增加等，都令到结构成本的增加。

单是作為其中一个显著的元件的规模，已使高层建筑的结构成为一个值得研究的建筑元件。 在平安中心项目，我们进行了下面一些方案的成本研究/比较:

- Verendeel与带状桁架(Belt Truss)方案
- 钢筋混凝土结构与型钢结构于裙楼結构方案
- 标准层採用标準钢梁和非标準钢梁方案
- 标准层楼板採用型钢装饰板和非型钢装饰板方案

在以上所述的方案的成本研究/比较中，最终的选择都并非按其成本的高低，反倒是其他方面，如建筑施工的相对快慢，及那些方案具备结构尺寸较小优势等，成为业主和设计团队的主要考虑因素。

外立面

除了作为建筑物的"外套"，并需能承受强风的影响外，外立面也是高层建筑最受到注目的元素。 大多数的情况下，客户和设计师将依靠外立面的外观设计，来营造高层建筑突出于周围的建筑物的标志性形象 (见图2.17) 。 因此，外立面最有可能被设计成具有某些特色的或独特的特征，构成外立面的造价成本上升。

以下是外立面不同的部件，需要在成本规划时特别注意:

- 外立面如幕牆系统
- 外立面照明，使高层建筑在夜间在很远的距离仍可见
- 擦窗机系统，需要有足够的安全设备以便在强风下运作。此外，标志性的建筑物的形状可能需要不同的擦窗机系统来提供不同部分的清潔。例如，在平安中心项目，总共有十个擦窗机系统被提供。

Figure 2.16. Construction of the deep basement (Source: Ping An)
图 2.16 深地下室施工 (来源: 平安)

perceivable element of tall buildings. In most cases, the client and the designer rely on the façade design to create an iconic image of the building, especially where the tall building stands out from the surrounding buildings in the city's skyline (see Figures 2.17). In such an application, the façade would most likely be designed with some special or unique features, which constitute the higher unit cost of the façade.

The following are the various façade components that require special attention in cost planning:

- The façade system itself
- Façade lighting, which allows the tall building to be visible from a distance at night
- Window-cleaning system, which has to account for a high wind speed, and necessitates cast-in anchors to secure it to the façade. The iconic form or shape of the tall building may also necessitate different types of window cleaning systems. For the Ping An project, a total of 10 window-cleaning systems have been provided.

The following are some of the cost studies/comparisons that were carried out on Ping An :

- Different types of glass
- Different façade lighting schemes including the power consumption

下面是一些我们在平安中心项目所进行的成本研究/比较：

- 不同类型的幕墙玻璃方案
- 外墙照明方案，包括功耗对比

我们的角色是专注于在设计的每个阶段对外立面总成本费用估算的检查。

在平安中心项目中，有一个比较有趣的案例，是关于尖顶方案的:

- 方案1 尖顶的高度增加12米
- 方案2 -尖顶的高度为原设计
- 方案3 -尖顶的高度减少28米

Figure 2.17. Installation of the façade (Source: Ping An)
图 2.17 独特外墙的安装 (来源: 平安)

The author's role was focused on checking the total façade cost at each stage of the design.

One interesting feature of Ping An upon which cost comparisons were carried out was the spire. The following were considered:

- Option 1 – Spire reaching 660m high
- Option 2 – Spire reaching 648m high
- Option 3 – Spire reaching 636m high

Notwithstanding that the construction cost of Option 1 is obviously the highest, followed by Option 2 and then Option 3, the three options had different implications on the structure. For Option 1, redesign of the spire structure including both the base and the mast, and recheck of the main structure would have been necessary, which would take seven weeks for re-design and re-evaluation. Whereas for Option 3, re-design of the spire structure is required only, and would take five weeks for re-design and re-evaluation.

Architectural Works, Finishes and Fitting-out of Public Areas

Although these elements are area-and-quality related rather than height-related, one would expect the unit cost to be generally marginally higher than that of typical buildings, since internal finishes of tall buildings are generally at the uppermost end of the cost range to project the prestigious image of their occupants.

Another observation is that for tall buildings, the ground-floor story height is usually comparatively higher than that of typical buildings, which, according to some designers, provides a better proportion for the whole building and at the same time offers the grandness of the reception lobby of a prestigious tall building. For Ping An, the ground-floor story height is 12 meters and the clear headroom is 9 meters. The fitting-out cost of the ground-floor lobby is therefore comparatively much higher than normal lobbies of 4 – 5 meters clear headroom.

尽管方案1的建造成本显然是最高的，其次是方案2，然后为方案3，但3个方案则有不同的时间影响。 对方案1来说，塔尖结构包括底座和桅杆需重新设计，并且要重新检查塔顶的主结构，将需要7周的时间包括重新设计和重新评估。至于方案3，则仅塔尖结构需要重新设计，而需时为5周。

建筑装饰和公共区域装修

虽然以上元素的成本造价，一般是和其所占的面积和质量相关，而并不是和建筑物的高度相关的，但因为高层建筑的内部装修一般都为档次较高，以切合项目的高端形象，所以高层建筑这方面的成本造价亦较一般的建筑物普遍为高。

我们另一个观察所得是，高层建筑的地面层高度通常是相对一般的建筑物为高。据一些设计师的说法，高层建筑的地面层较高能提供整幢建筑更好的比例，并在同一时间为高层建筑提供了一个宏伟的接待厅，以平安中心项目来说，其地面层高为12米而净空高度为9米。 所以，相比一般的建筑物，假设其地面层大堂为4 - 5米的净空高度，平安中心项目的地面层大堂的装修成本就相对较高。

电梯配置

由于有更多数量的电梯而电梯普遍较为高速，高层建筑的电梯成本造价相比一般的建筑物要高。高层建筑通常采用多区电梯系统，以减少乘坐和等待的时间。此外，高层建筑有时会配置双层电梯系统来增加载客容量而不增加电梯升降槽所占用的面积。

对不同的电梯配置方案作成本研究/比较，在高层建筑是很普遍的做法。但除了不同的电梯配置方案间的成本差额外，大家亦必须考虑不同的电梯配置方案对电梯升降槽的空间需求 (即其对楼层有效面积率的影响)，以及不同方案的电梯等候时间等，综合考虑。

关于平安中心项目，其最终采用了的电梯方案包括有7个办公楼层区，2个空中大堂楼层和1个观景楼层，整体是透过3台高速电梯 (超过10米/秒)，12台高速穿梭电梯 (7-9M/秒)，36台双层客运升降机 (3.5 - 11米/秒)， 4台高速服务升降机 (10米/秒) 和另外2台电梯来提供服务。

建筑设备

和电梯系统相类似的，高层建筑的高度意味著系统长距离的运行，而这正是机电系统设计的主要考虑。对于与水有关的机电系统，这也意味着为供应和接收排放系统带来较高的水压。而若所有的楼层的供给或者所有楼层的污水都是通过一个单一的系统来收集，则该供给或收集的管道尺寸也将是极为巨大且会占用一定的楼面面积的。 因此，在大多数情况下，高层建筑的机电系统会分为不同的区域，每个区域有自己的机电层放置主要的机电设备等。 由于这种安排所需要的作为转移和分发每个区域内的泵和机械设备的额外数目，导致更高的成本造价。

高层建筑机电系统的分区域配置安排，往往带来了很多不同的设备组合方案，供进行研究和考虑。 下面是两个出现在平安中心项目的个案。

冷冻水系统配置方案比较

这个案是为ACMV系统下的冷冻水系统不同设备配置方案的比较。冷冻水系统所需的最大瞬时冷负荷约为17,000 RT而紧急冷冻水冷负荷约为1400 RT。共有6个不同的设备配置方案如下(见表2.1)：

尽管成本相对最高， 方案(2) 因能够提供了最具弹性的冷却水供应以及最低水压而在技术考虑下被最终采用。

Elevator Provision

The cost of elevators in tall building is much higher than other standard buildings due to the fact that there are more elevators and the elevators are high speed. Multi-zone elevator systems are usually adopted for tall buildings to reduce both the time of travel and waiting time related to the number of stops. In addition, to increase capacity while limiting the space taken up by the elevator shafts, sometimes double-deck elevators are employed.

Cost studies of different elevator arrangement options are common for tall buildings, but the difference in cost of different elevator provisions have to be weighted against the consumption of floor space by the elevator shafts / elevator circulation spaces (i.e., the impact on the efficiency of floor plans), the waiting time of different elevator arrangements etc.

For the Ping An project, the elevator scheme finally adopted comprises seven zones of office floors, two sky lobby floors and one observation floor, and served by three high speed elevators (over 10m/s), 12 high speed shuttle elevators (7 – 9m/s), 36 double deck passenger elevators (3.5 – 10m/s), 4 high speed service elevators (10m/s) and 2 other elevators.

Building Services

The height of tall buildings means long service run distances, and this has been the main consideration in the design of building services systems. For water-related systems, it also means higher water pressure, for both the supply and discharge systems. The size of the pipeworks would also be enormous if all the floors were to be supplied, or if all effluent from all floors were to be collected by a single system. Hence, in most cases, the building services systems of tall buildings are divided into separate zones, each with its own plant located on intermediate plant floors. With this arrangement, an extra number of pumps and major plant are required for transfering

Option 方案	For total cooling load 最大瞬时冷负荷配置	For emergency cooling 紧急冷冻水冷负荷配置	Order of Total Cost 成本高低排序 (1为最高)
1	Water-cool chillers at basement, 5 heat exchangers at different refuge/M&E floors 水冷式制冷机组在地下室，5组换热器在不同的避难所/机电层	3 air-cooled chillers at different refuge/M&E floors 3组风冷式冷水机组在不同的避难所/机电层	6
2	Similar to (1) but 10 heat exchangers 类似于 (1)，但共10组换热器	7 air-cooled chillers at different refuge/M&E floors 7组风冷式冷水机组在不同的避难所/机电层	1
3	Similar to (2) but different arrangements of the equipment 类似于 (2)，但设备的不同安排	Same as (2) 同 (2)	4
4	Water-cooled chillers at basement level, air-cooled chiller at 4th M&E floor, 6 heat exchangers at different refuge/M&E floors 水冷式制冷机组在地下室，风冷式冷水机在第四层机电层，6组换热器在不同的避难所/机电层	4 air-cooled chillers at different refuge/M&E floors 4组风冷式冷水机组在不同的避难所/机电层	5
5	Similar to (4) but 8 heat exchangers 类似 (4)，但8组换热器	7 air-cooled chillers at different refuge/M&E floors 7组风冷式冷水机组在不同的避难所/机电层	2
6	Similar to (4) but 7 heat exchangers 类似 (4)，但7组换热器	Same as (5) 同 (5)	3

Table 2.1. The six equipment arrangement options for chilled-water schemes.
表2.1.为冷却水方案准备的六套设备布置预案。

Option 方案	Equipment 设备	Order of Total Cost 成本高低排序 (1为最高)
1	6 10KV, 2000KW gensets interchange with city supply at HV supply 6组10KV，2000KW发电机组备用电源，和10KV 电可互相切换	2
2	6 No. 10KV, 2000KW gensets with own transformers to provide LV supply directly 6组10KV，2000KW的发电机组经由自己的变压器直接提供低压电源	1
3	6 No. 0.4KV, 2000KW gensets to provide LV supply directly 6组0.4KV，2000KW发电机组直接提供低压电源	4
4	4 No. 10KV, 2000KW gensets with own transformers and 2 No. 0.4KV, 2000KW gensets to provide LV supply directly 4组10KV，2000KW的发电机组经由自己的变压器和2组0.4KV，2000KW发电机组直接提供低压电源	3

Table 2.2. The four equipment arrangement options for emergency power supply.
表2.2.为应急电源准备的四套设备布置预案。

and distributing services within each zone, resulting in higher costs.

The subdivision of the building services systems into different zones allows different combinations of equipment to be studied and considered. The following are two systems studied for the Ping An project.

Chilled-Water Schemes
This case is for the equipment arrangement for chilled water production under the HVAC system. The total cooling load required is 17,000 RT and the emergency cooling load required is 1400 RT. Six different options of equipment arrangement were studied (see Table 2.1).

Although the cost is comparatively the highest, Option 2, which offers the most scalable chilled water supply with the lowest water pressure, was finally adopted out of technical considerations.

Emergency Power Supply Schemes
This case is for the equipment arrangement for emergency power supply systems. Four different options of equipment arrangement were studied (see Table 2.2):

Option 4, which offers high-voltage supply to high zones to minimize power loss, and low-voltage supply to low zones is, finally adopted out of technical and financial considerations.

The above cases demonstrate that building services design of tall buildings is a complex undertaking, and there are many areas for which one can consider different options. The most appropriate option must be selected through careful studies.

Conclusion

With the advancement in construction technology and scarcity of land resources, the author's view is that, where there is a financially justifiable business case, it is envisaged that developers would like their buildings to go higher, but there are hurdles like government regulations and environmental issues to be observed and overcome. Cost planning and control of the construction cost is therefore an essential part in the assessment of the financial viability of any tall building project. As demonstrated in the Ping An case, cost assessment relies on establishing a realistic overall budget through awareness and understanding of the cost-significant features of tall buildings, and significant efforts in tracking the design developments and offering cost advice and cost comparisons for various design options to make it successful.

应急(备用)供电模式方案
这个案是作为应急(备用)供电系统的设备布置4个不同的设备布置方案的比较 (见表2.2) :

方案4，提供高压电源以减少功率损耗供应高区，和低压电源供应低区，在技术和财务方面的考虑下而最终被采用。

以上案例说明了高层的建筑设备设计是一项复杂的项目，其中的许多方面都存在多个选项。最合适的选项一定要通过仔细的研究才能选出。

结论

随着建筑技术的进步，和市中心区可供发展土地资源的越来越稀有，我的看法是，只要是一个经济上可行的方案，开展商都希望他们的项目能建设得越来越高，但当然需顾及政府的法规和限制，以及环境问题等。 因此，成本规划和建设成本的控制是任何高层建筑项目的财务可行性评估的重要组成部分。在平安中心项目上，有关的成本规划和建设成本的控制体现在，对高层建筑的成本的特点有深刻认识和了解，从而建立了一个现实及全面的成本预算，并在追踪设计开发和提供造价建议和成本比较方面不遗余力，才能达至成功的。