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Shanghai Tower: Building a Green, Vertical City in the Heart of Shanghai

上海中心大厦: 建于上海心脏地带的绿色垂直城市



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Abstract

The Shanghai Tower establishes a new paradigm for tall buildings and vertical urbanism. This paper provides an overview of the strong role that innovation and new technology play in the superlative aesthetic, structural and environmental achievements of this “disruptive” building, while reinforcing time-honored maxims of design that still hold true.

Keywords: Shanghai Tower, Vertical City, Community, Technology, Environment, Revive

摘要

上海中心大厦作为一栋具有颠覆性意义的大厦, 为超高层建筑和垂直城市化实践建立了新的案例。本文对上海中心大厦在未来垂直城市发展的研究、振兴区域发展、创新技术、环境保护进行概述, 展现其提供未来使用者安全、舒适、便捷的工作和生活环境的目标, 而不是仅仅用更多的投资建造一栋更高的建筑物。

关键词: 上海中心大厦 垂直城市 社区 技术 环境 复兴

Introduction

The Shanghai Tower is one of the most ambitious skyscraper projects ever undertaken on the planet, let alone in China. The 632-meter “megatall” building will establish a new paradigm in the tall-building typology, in a way that embodies the theme of this year’s Conference, “Future Cities: Towards Sustainable Vertical Urbanism.” While the distant silhouette and the proximate detail of the tower will be immediately distinctive (see Figure 1), the purpose of the Shanghai Tower is not simply to be seen as an iconic landmark. It is much more than that. Because it incorporates so many advanced techniques based on current skyscrapers, it will be a learning laboratory for the next generation of skyscraper designers. And it illustrates that architecture should not be constructed for its own sake, but for the “people,” which is the most fundamental factor. This paper provides a succinct overview of some of the ideas, motivations, challenges, advances this project that will provide practitioners valuable information that can be used on their own future projects.

Motivation: Built for People

Tall buildings are often seen as iconic landmarks, which encourages one to take an external view only. But in order to achieve “sustainable vertical urbanism,” skyscrapers must turn their focusing point from ROI of

引言

不仅在中国, 在全世界范围内, 上海中心大厦是有史以来最雄心勃勃的超高层建筑之一。这座高632米的巨型结构建筑将建立一个高层建筑类型学的新模式。这个概念与本次会议主题不谋而合: “未来城市: 迈向可持续垂直城市主义”。虽然建筑的远景轮廓和近景细节均具有很强的识别性, (见图1) 但上海中心大厦的意义不应该被简单的看成是一个标志性建筑。它的意义远不止于此。它在已有的超高层建筑的基础上, 集成创新的理念和技术成果, 将为新一代摩天大楼设计师提供一个学习实践的园地。同时, 它充分表明建筑不是为建造而建造, 它的根本是为“人”而建造, 所以“人”将是最重要的要素。本文对该项目的理念、动机、挑战、创新进行介绍, 希望能为业内同行提供有价值的参考信息。

目的: 为使用者而建造

高层建筑往往被视为引人注目的地标, 其标志性使观察者仅仅关注其外观形象和高度。但是, 为了实现“可持续垂直城市化”, 必须改变人类传统的投资回报率, 把人、具体是使用者的需求作为最重要的因素考虑, 才能成为真正永恒、甚至是激动人心的建筑。

上海中心大厦通过双层幕墙的设计, 创造出独特的空中大堂, 其中充满着自然绿化的元素和潜在的社交活动空间, 在不降低建筑高度的情况下缓解高层建筑的孤立性, 从而展现了一个整合垂直空间的图



Figure 1. Shanghai Tower rendering (source: Shanghai Construction Group)
图1. 上海中心大厦效果图 (出自: 上海建工集团)

human experience to people and specifically the users' demands to become enjoyable, even exhilarating architecture.

Shanghai Tower provides a vision of vertically integrated space through the signature design of double façade that create unique sky lobbies, filled with vegetation, potential for socializing, and relief from the isolative nature of tall buildings without the necessity of descending to the ground. But why do this? Is this design arrived at arbitrarily, or through assumptions?

A typical return on investment (ROI) calculation subtracts the cost of investment from the gain from investment. But when planning buildings as vertical cities, they must be thought of as systems. Importantly, traditional ROI calculations also overlook the value of human capital – the people who occupy the building.

An expanded ROI calculation considers that sustainably designed buildings can reduce sick time by two to five days annually and increase productivity by 4.8 percent. When one is designing a skyscraper to accommodate more than 20,000 people, the value of that productivity increase justifies the extra expense of what we call "reinventing the chassis of the high-rise."

The biggest distance between outer curtain wall system and the main structure in Shanghai Tower is 15 meters, this avoids about 20,000 office staffs and hotel guests from directly facing with the outdoor in an altitude of several hundred meters and erases people's fear. The presumable 5% people suffered from acrophobia could work relieved and calmly in Shanghai Tower. This is another value in increasing productivity.

景。这种方式的目的是什么? 它是否是随意而为之, 或主观假设而来。

传统的投资回报率(ROI)计算方式是投资收益减去投资成本。但在规划建筑物作为垂直城市时, 必须系统性地思考。重要的是, 传统的投资回报率忽略了人力资本的价值, 即大楼后续使用者的因素。

如果采用广义投资回报率的计算方式, 可持续发展的建筑物平均每年每人可以减少两至五天的病假, 并提高4.8%的生产效率。当摩天大楼容量每天超过20000人工作时, 生产效率增长所带来的回报证明我们对高层建筑可持续设计和投资是非常值得的。

上海中心大厦双层幕墙最远的距离有15米, 使其中办公人员和酒店客人约20000多人避免直接面对室外数百米的高空, 大大降低了人们对高空的恐惧感。如果其中有5%的人患有程度不同的“恐高症”, 在上海中心大厦, 这些人可以安心、平静地工作, 这又是一个生产效率提高的价值。

还有, 当大厦内5%、1000个人, 每年有十次不需要在城市不同的地点、平均用半个小时交通时间, 进行面对面工作或参加活动。只要在几分钟内就可以坐下来商务谈判、协调事务、参加活动时, 可以减少5000小时的交通时间的浪费, 可以减少交通拥挤和汽车尾气对空气的污染。

社区: 非单纯的建筑物。

现代建筑物越来越豪华, 经济的属性成为主要的指标, 而人与人之间沟通交流的空间却越来越缺乏。但是, 随着人类经济和生活水平的提高, 人们回归自然、增加沟通、舒适方便生活的需求在不断的提醒我们应该如何建造高层建筑

上海中心大厦引入“垂直社区”、“社区广场”和“空中花园”的概念。“垂直社区”就是将传统的水平街区在高层建筑中垂直迭合成9个街区, 每个街区有相对独立的空间。“社区广场”就是间隔十多米的双层幕墙创造了独特的参与式空间, (见图2和3) 在每个社区形成3个空中大堂, 即“社区广场”, 这些“社区广场”高度有50至60多米, 整栋建筑共有21个“社区广场”。这些“社区广场”集成了能源效率、垂直交通转换、消防和生命安全的要求, 同时还为用户提供额外的休息、社交、观景、简餐、金融的服务。“空中花园”就是在不同高度的“社区广场”中种植花草树木, 形成立体的绿化景观。上海中心大厦系统的在超高层建筑众引入社区、广场、花园的设计, 这在世界超高层建筑中是独一无二的。

上海中心大厦还采用了“垂直复合功能”的设计。除了有传统的购物(1区)、办公(2到6区)、酒店(7到8区)、观光(9区)等不同功能的街区组合而成。同时, 还在不同的“社区广场”中引入了公共博物馆(37层)、美术馆、创意生活(地下1层、52层、53层)、健身设施(22层)、艺术展览、文化活动, 为社区的使用者提供全新的工作之余的生活体验(见图4)。

技术: 为可持续而创新。

上海中心大厦在满足建造的同时, 重点在建筑可持续发展技术创新上进行研究和探索。

建筑外形是所有设计师和投资者所关注的。上海中心大厦不仅考虑外形的优美, 还关注其结构安全和节约投资。它螺旋上升, 旋转120度, 除了符合优雅、时尚这种上海城市特色外, 经过风洞试验, 还可以减少24%的风荷载, 减少约2万吨钢结构, 这对处于每年台风袭击的城市是非常重要的。



Figure 2. The atrium between the façades at Shanghai Tower
图2. 上海中心双层幕墙之间中庭

What more, 10 times a year 5% of the people in the Tower which is about 1000 people need to be at the same places in the city for face-to-face working or activities and spend half an hour in the transportation. If they only need several minutes to seat together for business negotiation, coordination, activities, 5000 hours of transportation time could be saved and also the traffic congestion and pollution caused by automobile exhaust could be reduced.

Community: More Than Mere Constructions

The modern building are getting more and more extravagant, the economic statistics are becoming the dominant factors and the communication space for people are been gradually ignored. However, with the development of financial conditions and life standard of human, the calling for going back to nature, enhancing communication, cozy and convenient life is consistently inspiring us of how to design tall buildings.

Shanghai Tower has introduced the concepts of "Vertical Community", "Community Square" and "Sky Gardens". "Vertical Community" is to overlap traditional horizontal blocks into 9 vertical communities each equipped with private space. "Community Square" is the unique participatory space in between the double layer façades which are over 10 meters wide (see Figures 2 and 3). Every community has 3 sky lobbies – "Community Square" whose height range from 50 to 60 meters, the tower has 21 "Community Square" in total. They fulfill the requirements in energy efficiency, vertical circulation, fire defense and life security and at the same time provide complementary service of relaxation, social contact, viewing, catering, financial. "Vertical Community" is to plant flowers and trees in "Community Square" in various height and create a vertical greenery. Shanghai Tower has systematically introduced the design of communities, squares, gardens in skyscrapers which is unique in tall buildings around the world.



Figure 3. the atrium design of Shanghai Tower (Source: Gensler.)
图3. 上海中心大厦中庭设计 (出自: Gensler.)

由于建筑的复杂性，设计师有责任在建造完成后的使用阶段继续衡量其性能。结构性态检测系统 (SHM) 有助于监控在地震、风力、温差影响下的动态监控风险、质量水平、结构状态，提供安全警告和维护检查信息。结构性态监控系统 (SHM) 能够检测在特殊环境下的建筑位移、沉降、结构应力和应变、以及塔楼倾斜的情况。

智慧化建筑是上海中心大厦区别于传统的智能化建筑的一项工作。其大量使用当代先进的数字化技术和IT领域重大的进步技术，如首次在商业楼宇中建造云计算设施、物联网和BIM技术。它包含了由基础层的支撑系统 (综合布线、设备)、中间层的31个智能化子系统 (火灾报警、公共广播、楼宇控制、能源监控、一卡通、通信等) 和顶层的楼宇管理系统 (IBMS, 集成所有子系统数据采集、存储、处理、分析和显示)。所有的数据传输系统是以互联网 (IP) 为基础，并有10GB主干和1GB的IP网络服务于90%的智能子系统。

利用BIM设计和建造上海中心大厦的目的是精细化实施此项目，并提出了全生命周期概念。为了实现这一目标，利用Autodesk Vault的数据管理平台，管理和集成各种三维数据。业主专门成立一个工作小组，所有设计、施工、供应商成立BIM团队参与进来，建立了一个统一清晰、分层次的工作体系和标准。如外幕墙使用BIM后，制图效率增加了200%，处理图纸数据的转换效率提高了50%，复杂组件的测量效率提高了10%。对于MEP的影响，使用BIM后，减少了60%的现场工作量，70%管道预拼装成为可能。总之，使用BIM将削减3%至5%的因后期设计变更和人

Shanghai Tower has adopted the design approach of “vertical compound functions”. Except the traditional shopping mall (Zone 1), office (Zone 2 – Zone 6), hotel (Zone 7 – Zone 8), sightseeing (Zone 9) there are versatile function blocks. Public museums (37 floor), Gallery, creative life (B1, 52 floor, 53 floor), fitness facilities (22 floor), art exhibition, cultural activities are introduced into “Community Squares” and providing fresh life experience for the people in the communities (see Figure 4).

Technology: Innovate for Sustainability

Besides fulfilling the requirement of construction, Shanghai Tower has primarily studies and researched in the innovative technologies of sustainability.

The external view catches attention of designers and investors. Shanghai Tower not only considers for a elegant form but also keeps an eye on the structural safety and cost saving. It show the elegance and fashion characteristics of Shanghai by twisting the outer enclosure by 120 degrees while spiraling up. Through wind-tunnel test we know that the wind load could be reduced 24 percent which is quite considerable in a city suffered from typhoon every year and 20,000 tons of steel could be saved.

Given the complexity of the building, it was incumbent upon the designers to continue to measure its performance, even as it was being built, with a view toward continuous monitoring after completion. The structural health monitoring (SHM) helps dynamically observe risks, quality level and structural states under loads, providing safety warnings and information for maintenance and inspection. The SHM monitors seismic response, displacement and settlement, structural temperature, stress and strain, and tower structure inclination.

Shanghai Tower has distinct itself from traditional intelligent buildings as a smart building. The design and construction of Shanghai contemporaneous with sophisticated digital technology and major IT advances, such as cloud computing for the first time in commercial buildings, the internet of things, and BIM. The tower contains basic support level(cabling system, equipment), middle layer of 31 intelligent subsystems (fire alarm and public-address systems, Building Control System for facilities, energy monitoring systems, a one-card security pass system, and an integrated communications system) and top layer of Intelligent Building Management System (IBMS, which integrates the collection storage, processing, analysis and display of data from all subsystems). The transmission system for all of this data is Internet Protocol (IP)-based, and a 10-GB backbone and 1-GB IP network serve 90 percent of the intelligent subsystems.

The objective behind using BIM to design Shanghai Tower was to execute the project using Lean management techniques and to realize the full life-cycle monitoring concept. To achieve this, Shanghai Tower's design team used Autodesk Vault Professional, a data-management platform that can manage and integrate data from various programs. The client established a working group involved all the BIM teams from design, construction to supply and form a working framework and standard unified by a clear hierarchy. For example, by using BIM on the external curtain wall, the efficiency of drawing processing maps increased by 200%. The conversion efficiency of processing map data has increased by 50%, while the measurement efficiency of complex component increased by 10%. For the MEP disciplines, using the BIM framework cut 60 percent from onsite workloads and allowed pipeline assembly to be 70 % prefabricated. All told, using BIM cut 3 to 5 percent of the total project cost that is normally devoted to post-

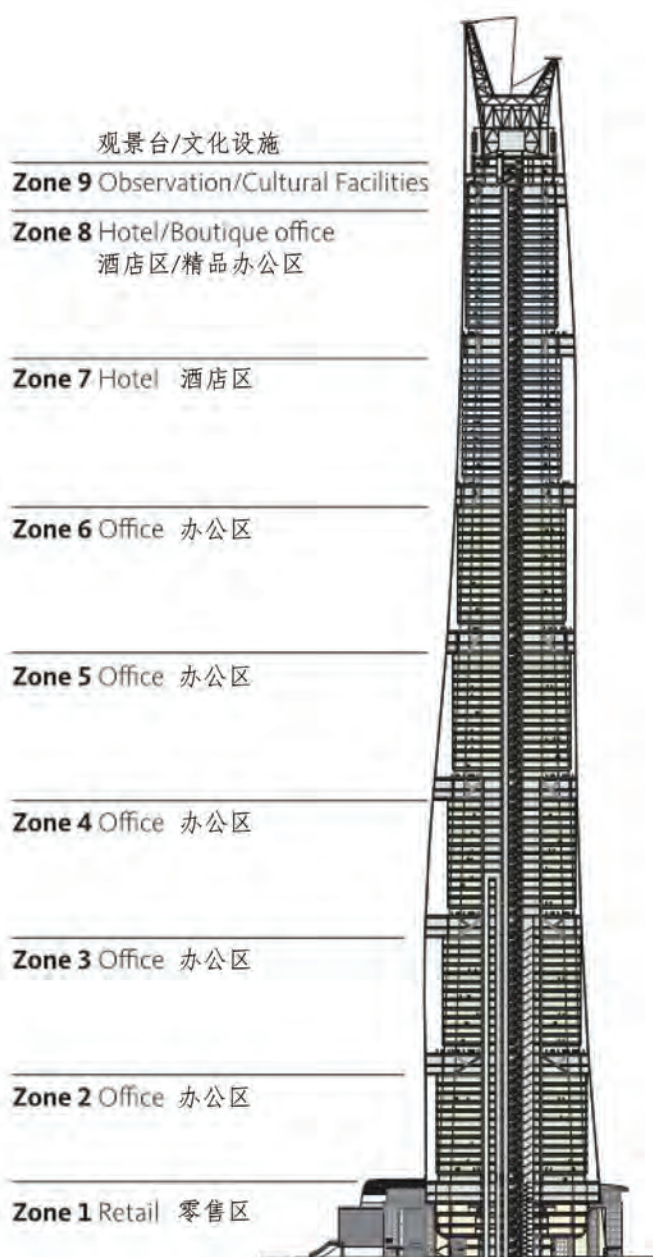


Figure 4. The vertical zones of Shanghai Tower organize the tower into a vertical city. (Source: Gensler)

图4.上海中心的垂直分区让塔楼成为了垂直城市 (出自: Gensler)

栋超高层建筑既有相互协调，又有自己独特的个性。在建筑高度选择上，按照目前我们的建造技术，完全可以盖更高的建筑，但是，不能破坏城市天际线。所以，最后选择了632米，比附近的金茂大厦高210米，比环球金融中心大厦高140米，在三足鼎立的三栋超高层建筑之间形成70米、140米螺旋上升的高差。

自始，上海中心大厦就竭力要成为目前世界上最高的绿色建筑，严格按照中国绿色建筑三星标准和美国LEED金级标准双认证的要求，系统性地集成了47项环保节能技术。虽然，这将会增加比同类建筑高3%到5%的工程投资，但能达到中国能耗标准下的54%的节能率、美国标准下的22%节能率。它的解决方案包括双层幕墙体系比单层幕墙能耗可以降低50%，一个热电冷三联供系统 (CHP)、地源热泵系统，冰蓄冷系统，两个能源中心 (低区地下2层和高区82层)，风力发电系统每年可发电119万KWh电量，25%的

design changes and human error, while cutting clashes had a value of more than 100 million RMB (US\$16 million). The role of BIM technology will not end on Shanghai Tower's opening day, it is been studied how to apply BIM in the asset management of the tower and continue to be used as part of a Property Asset Operations Platform (PAOP), comprising BIM, Facilities Management (FM) and IBMS technologies.

Environment: Responsible Development

Tall buildings have significant influence in the urban features and regional environment, the client and designer must hold a principle responsible for the contemporary and also the descendant.

In the determination of the final scheme of Shanghai Tower, we had sufficient consideration of the influence that architectural form and building height have on the city. The tower spirals up in a gentle trend and harmonizes with the two skyscrapers nearby while maintaining its own characters. In the decision of building height, the current technology could absolutely allow for more remarkable height. However, in order not to break the city's skyline we eventually choose 632 meters which is 210 meters higher than Jin Mao Tower and 140 meters higher than World Financial Center, thus these three building form a altitude difference of 70 meters and 140 meters.

From the outset, the ambition behind Shanghai Tower was to make it one of the world's greenest and best-performing tall buildings and stringently meet the requirements of Chinese Green Building Standard and LEED gold standard by integrating 47 sustainable energy saving technologies. Although this would increase the project investment by 3% to 5%, the building supports an energy saving rate of 54% over the Chinese efficiency standard and 22% over the American efficiency standard. Active solutions include a double layer curtain wall which saves 50% energy than single layer façade; A combined cooling and heating power (CHP) system; two energy centers (Level B2 at the low zone, Level 82 at the high zone); wind turbine system could generate 1,190, 000KWh electricity every year; 25% Greywater are used to flush lower-area toilets and road, irrigate plantings; 92% percent material are purchasing within a distance of 800 miles; 60% waste are recycled and reused; most space of the tower are illuminated with currently most energy saving LED light, and controlled by a automatic ON and OFF system with brightness sensors.

After the handover of the building, Shanghai Tower has deployed a huge monitoring system in order to ensure the operation of sustainable measures and to monitor and control all the energy consumption. A Central Energy Management Control System (CPMS) are studied to integrate the energy conditions in different seasons and time periods and form an application model of peak probability and control the operation time of energy equipments. With the successful application of CPMS, 10% to 15% more energy will be saved. This would be the debut of this technology in such mega-scale, complicated buildings worldwide.

Revive: Contribution for the Regional Development

Iconic buildings usually have significant influence on the regional development. Therefore investors should not only focus on their own benefit but have sufficient consideration of how to contribute for the regional development and function improvement.

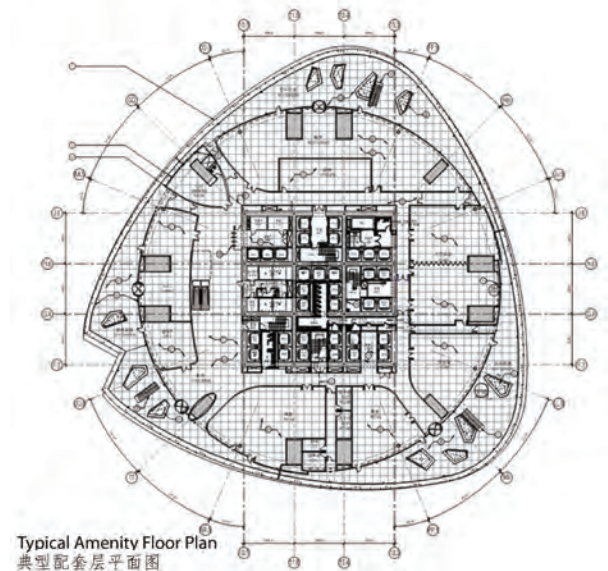
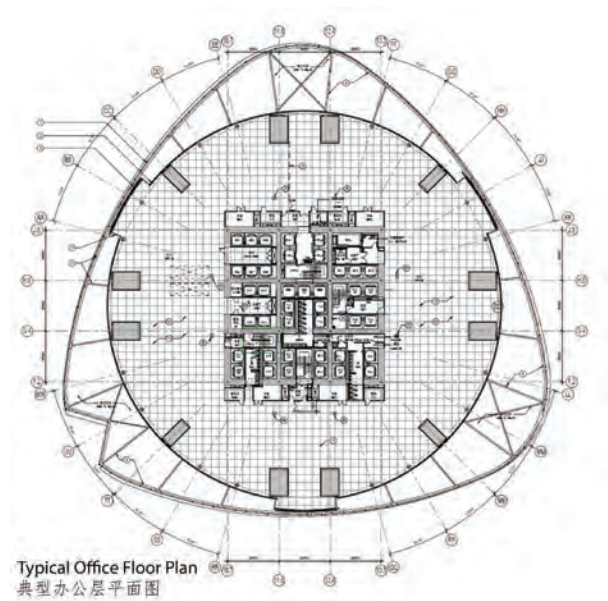


Figure 5. Shanghai Tower Typical Floor Plans (Source: Gensler)
图5.上海中心大厦标准层平面图 (来源: Gensler公司)

中水将被重复使用于冲洗厕所和路面及灌溉绿化, 92%的材料采购半径不超过800英里, 60%的废弃物被回收利用, 大厦的大部分空间将使用目前最节能的LED照明, 建立了基于采光亮度的自动关闭和启动的控制系统。

当大厦投入使用后, 为了确保节能环保措施的使用, 上海中心大厦实施了庞大的监测系统, 对所有能源使用者的情况进行监测和控制。同时, 还在研究中央能源控制系统 (CPMS), 通过对不同季节、不同时间段的能源使用状况进行整合, 最终形成一个最高概率的适用模型, 用计算机对能源设备运营时间进行控制。如果CPMS成功地应用, 将在现有节能模式下再节能10%到15%, 这也将是世界上第一次在如此巨大规模、功能特别复杂的建筑物中使用这项技术。

复兴: 对区域发展的贡献

地标性的建筑往往会对区域的发展有重大的影响。因此, 投资者不能只限于自身的利益, 应该充分的思考如何为区域的发展、功能的完善做出贡献。

Shanghai Tower is located in the CBD of Shanghai Pudong District. We propose a new concept and design approach for CBD. Traditional Central business district are restricted in commercial concept. Shanghai Tower raise a new definition of CBD according to social development: Community, which is vertical overlapped; Business, which stands for leadership in business; Diversity, which emphasizes diversified culture. This extend the meaning of CBD from mere commerce to community and culture.

Considering the monotonous facilities in Pudong Lujiazui District, Shanghai Tower didn't set mere luxury retail during the programming arrangement, but start with a typology of "experience, technology, culture, future life, supporting service" and insert public museum, gallery, large gallery and supporting facilities of commercial to serve for 20,000 users in the tower and also 100,000 white collars in this region.

In the beginning of construction, Shanghai Tower has planned and constructed public passageways in the 2nd floor underground to supply the deficient underground traffic, connecting to Jin Mao Tower, World Financial Center, International Financial Center, metro Line 2 and metro Line 14 and established a complete pedestrian system underground.

Shanghai Tower was always conceived as more than a superlative of height, although it is also that. It was conceived as a new prototype for vertical cities, and its success will be dependent upon the hard work of the thousands of people involved in the project. Despite the obviously critical role that technology and innovations that we have described here plays in creating a vertical city with "height, pride, delicacy". It must never be forgotten that buildings are for people, and the objective of any building, no matter how awe-inspiring, is to function well in the support of human well-being.



Figure 6. The user enjoyment of the double façade space at Shanghai Tower is central to its design. (Source: Gensler)

图6.上海中心双层外立面空间带来的用户享受为其设计核心。(出自: Gensler)

上海中心大厦位于上海浦东金融城的CBD地区。为此，我们提出了新的CBD概念和设计。传统的CBD就是Central business district中央商务区，局限于商业的概念。上海中心大厦根据社会发展的新情况，提出重新定义CBD，C就是Community，即垂直社区；B就是Business，即商业领导力；D就是Diversity，即多元文化。把CBD的内涵从单纯的商业，扩大到社区、文化的领域。

针对浦东陆家嘴地区功能结构单一的问题，上海中心大厦在大厦业态定位时，没有简单地设置传统的奢侈品零售，而是从“体验型、科技型、文化型、未来生活型和配套服务型”入手，并增加了公共博物馆、美术馆、大型书店以及配套服务商业，不仅为本大厦近2万人、也为该区域10多万白领提供一些新的服务。

建造之初，由于该区域地下交通严重缺乏，上海中心大厦就在地下2层规划并建造了公共通道，连接周边金茂大厦、环球金融中心大厦、国金中心，并与城市2号线、14号线相连，形成了完善的地下人行通行系统。

虽然高度仍然是建筑无法被忽视的特征，但是，上海中心大厦被认为是一个垂直城市的新范式，并一直被视为具有其他的深刻意义，它的成功取决于成千上万个参与者的辛勤劳动。尽管本文列举的创新理念和技术在成就一座“至高、至尊、至精”的垂直城市起到了至关重要的作用，但我们始终遵循一句重要的格言：必须永远铭记建筑物是为人而造，并且任何建筑物的目标，无论多么崇高，都是为了实现更好的人类福祉。



Figure 7. Shanghai Tower in construction, Topped Out July 2014 (Source: TJAD)

图7. 施工过程中的上海中心大厦，2014年7月封顶(出自: TJAD)