

# Sky City – Grouped High-Rise

## 天空城市——群体高层的构想



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### Abstract | 摘要

*Ever since the development of Chinese urbanization, the supply of land for development in many cities has reached its limits. Apart from simply restoring old buildings, there are generally three ways to solve this issue, which could be put as: "to borrow from sky," "to borrow from underground" and to "enhance rural development." Among these three analogies, "to borrow from sky" seems obviously the most economical solution. However, the efficiency, safety and comfort of high-rise construction is restricted by modern technology. To tackle this issue, Jiang proposes the concept of the "grouped high-rise sky city," which contains two strategies: "vertical transportation and facilities constructed as municipal infrastructure" and "high-rise buildings divided into groups of multi-story buildings." The development of this concept requires the collective efforts from the government, the real estate industry, and academic researchers, the realization of which could help to bring about a more economical, efficient and green city.*

**Keywords: Centralized Utility System, Efficient Land Use in Urban Design, Fire Safety for High Rise Buildings, Grouped Super High-Rises, New Building System, Sustainability**

随着中国城市化的发展, 许多城市建设用地的供应已经达到了极限。除了简单地改造旧建筑之外, 总的来说有三种方式可以解决这个问题, 分别为: “向天借地”、“向地下要空间”和“向农村延展”。其中, “向天借地”似乎是最经济的策略。然而, 高层建筑建设的效率、安全和舒适度正在被现代的技术所限制。为了处理这个问题, 江院士提出了“组合高层建筑空中城市”的理念, 该理念包含两个策略: “垂直交通和设施构建作为市政基础设施”和“高层建筑分为多层建筑群”。该理念的开发需要政府、房地产行业 and 学术研究界的集体努力, 这个理念的实现可以帮助促进一个更加经济、更加高效更加绿色的城市。

**关键词: 集约化市政设施、城市设计中的节约用地、高层建筑的消防、群体超高层、新型建筑体系、可持续性设计**

With the development of China's reform and opening up over the last 30 years, many of the mega- and medium-sized cities have reached their maximum growth in area and population, which leads to the emergence of numerous metropolises.

A while ago, a series of satellite photos was provided to UN as part of the Chinese general geographic report. They clearly revealed the expanding of urbanized area around the world, some of which most related to our urbanization development are shown as follows (Figure 1).

The built land use of Shanghai has hit its ceiling. The Urban Planning Bureau issued a document titled Procedures to Regenerate Shanghai City on April 29, 2015, which contains valuable information. Some of the most appealing topics are: improving eco-system, exchange space with height and area awarding system.

Metropolises are now cramped with low-efficiency high-rise buildings of 100–200m.

在经历了三十多年的改革开放后, 中国所有的大中型城市都在覆盖地域及人口规模上经历了最大程度的增长, 涌现出众多超级城市。

不久前, 一位学者向联合国提供了一组航拍照片, 是中国常规地理报告中的一部分, 其中清晰地显示世界各地的城市化扩张进程。在此仅展示与我们城乡建设关系最密切的几张图片(图1)。

上海市建设用地已达到了极限, 规土局于2015年4月29日发布了《上海城市更新实施办法》, 内容颇多, 其中最令人感兴趣的是改善生态环境, 以高度换空间, 以及面积奖励机制。

许多超级城市里挤满了用地低效的一两百米的高楼, 越建越多的道路并没有缓解越来越挤的交通, 反而导致成片的绿地缺失, 建设用地也达到了极限。城市化在近期似乎是个不可逆的趋势, 目前城镇化率已达45%, 大量农村人口向沿海及各大城市迁移, 这种高密度的发展是始料不及却真实发生的。那么如何解决上述问题(图2、3)?

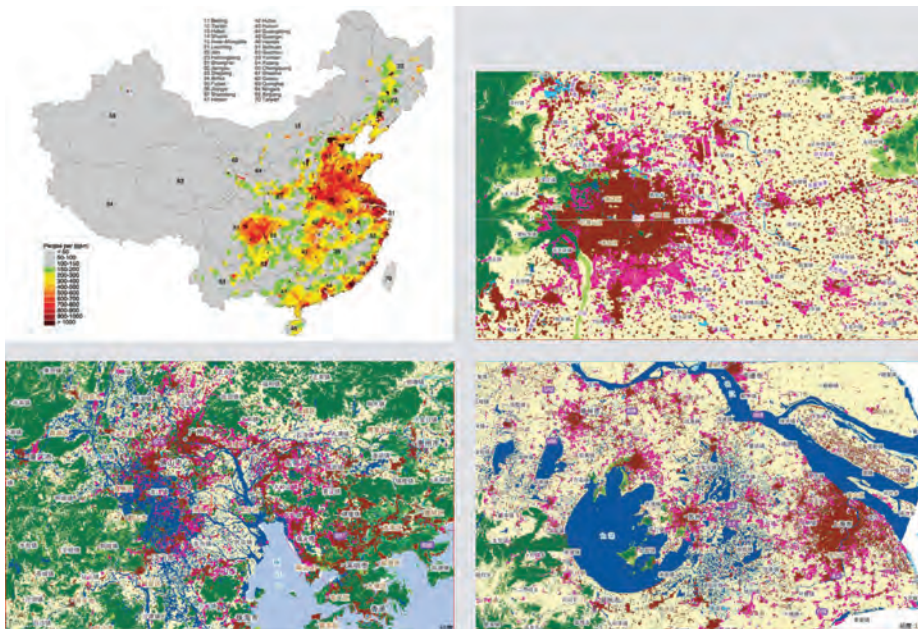


Figure 1. City expansion diagram (Source: Jiang Architects & Engineers)  
图1. 城市扩张分析图 (来源: 上海江欢成建筑设计有限公司)

Massive road network construction does not seem to relieve heavy traffic, but causes further loss of green area and keeps pushing the city to its limit. The construction of urban land in China is spreading like a storm. The current urbanization rate is just 45%. A large amount of rural population is migrating to megacities and cities on the coast. This development of high density is probably not what is expected, but is the reality. Where is the solution to all these problems (Figures 2 & 3)?

### I. Three Ways to Increase Land for Urban Development

There are generally three ways to solve the issues of limited land use, apart from restoration and renovations of old buildings: i.e., horizontal expansion to rural areas, "borrowing land from sky," and "borrowing space from underground."

**Exploring rural areas** means that agricultural land use will suffer. Our General Party Secretary, Xi Jinping, announced on May 26, 2015 that we shall protect lands like protecting pandas.

### 一、城市建设用地的三条出路

解决有限的建设用地问题,除了老建筑的整修和翻新外,有三条出路:①水平延展,俗称摊大饼,也即向农村延展;②向天借地;③向地下要空间。

**向农村延展**,必须付出占用良田好土的巨大代价。习近平总书记2015年5月26日指示,要像保护大熊猫一样保护耕地。

“摊大饼”的另一个问题就是基础设施尤其是交通路网跟不上,无法与城市化进程相匹配。高速越造越多,地铁越造越长,但高峰时段人们还是得在沙丁鱼罐头似的地铁里挤上个把钟头,或堵在道路上几个小时。

为什么理想化的卫星城市鲜有成功案例?因为商业社会里大部分行业的聚居模式并不能被个别“设计师”的意志转移。套用一句老话:地段、地段、还是地段。市中心始终拥有着无法抵御的诱惑,众多的文化活动、优良的服务设施、历史遗留的城市脉络,这些不是一朝一夕能在新城中形成的。

**向地下要空间**,已逐渐被人们认可和接受,新造高层建筑下往往有多至五层地下室,地下商业价值也不亚于地上商业。但若千疑虑包括:

- 造价太高。地下工程较贵是众所周知,地铁综合造价约为5~10亿元/km。
- 安全存疑。尤其在防水、防火、防毒、反恐等方面。万一出事,后果不堪设想。

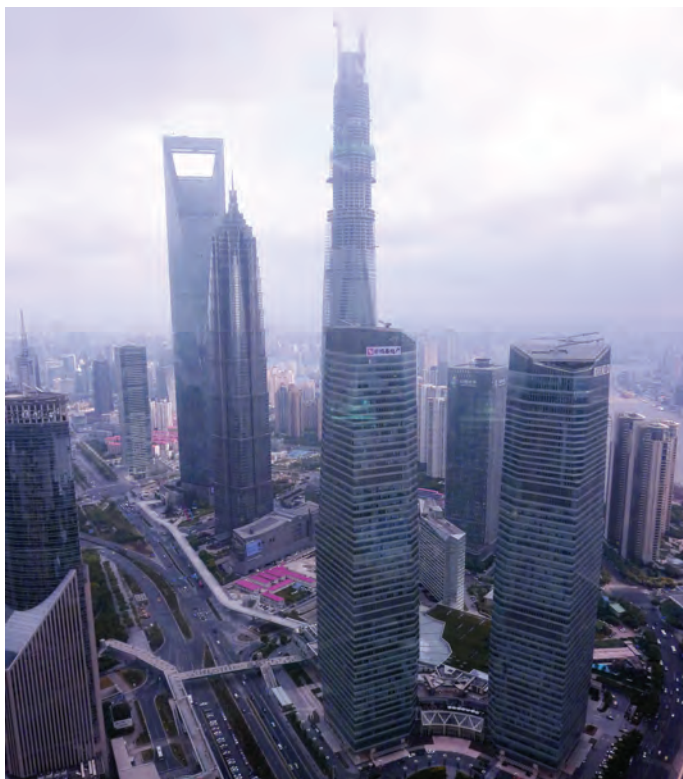


Figure 2. Current skyline of Lujiazui in Shanghai (Source: Jiang Architects & Engineers)  
图2. 上海陆家嘴天际线 (来源: 上海江欢成建筑设计有限公司)

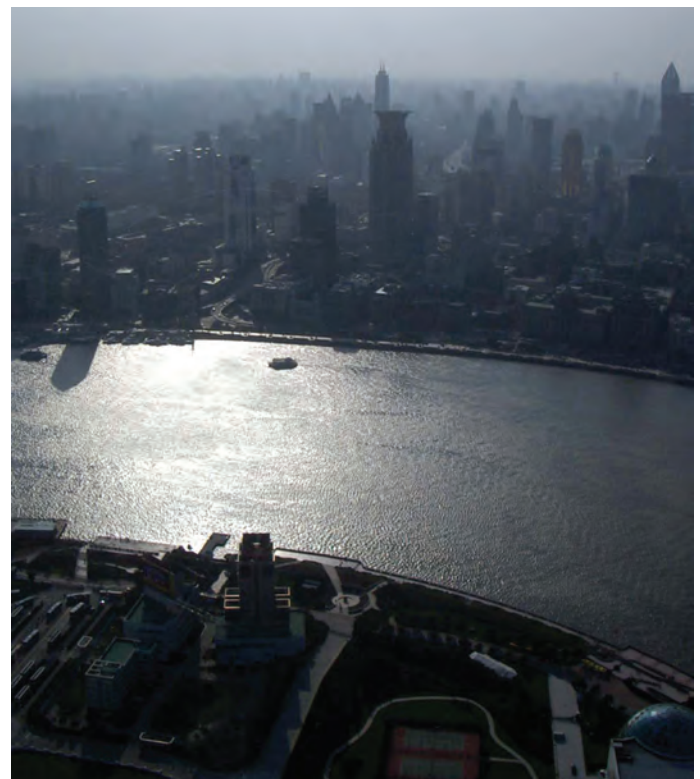


Figure 3. A forest of buildings (Source: Jiang Architects & Engineers)  
图3. 建筑森林 (来源: 上海江欢成建筑设计有限公司)



Plus, the construction of infrastructure, most importantly that of road networks, could not keep up with the pace of urban expansion. The extension of metro lines and highways only result in more severe traffic congestion during rush hours, which sometimes could last for hours.

Why have there been rare successful cases in building satellite cities around the world? The inhabiting pattern of most business is not determined by a few individual “designers.” As an old saying goes, what matters is Location! Location! Location! City centers still maintain their irresistible attraction, providing numerous cultural events, convenient service facilities and historical legacy, all of which could not be immediately achieved in new towns.

**Borrowing space from underground** has been gradually accepted by the public. Some super high-rise buildings even have up to 5 basement levels and the commercial value of which could be equally compared to the above ground. Nevertheless, concerns still exist about this strategy:

- Cost: the cost of underground construction is well known to be most expensive. The comprehensive cost of metro construction is about 0.5–1 billion RMB/km.
- Safety: especially on issues of water, fire and toxic protection and protection against terrorism. If accidents happened, the consequences are almost unacceptable.
- Comfortability: mechanically induced daylight and ventilation is obviously not as natural and desirable as being directly exposed to sunshine and fresh air on the ground.

By comparison, **“borrowing from sky”** is probably the most sustainable solution in all aspects, such as economy, eco-system and comfortability; therefore, the emergence of high-rises is inevitable. However, as the construction of high-rise buildings spreads, cities are turned into concrete forests, and have begun to repel human beings because of their shortcomings, i.e., low efficiency, large energy consumption, difficulty in fire protection, and distant and desolated human relationship. Architects and government officials are aware of these disadvantages and have started to make design improvements, such as refuge levels, green platforms and connecting corridors between buildings. However, a total solution has not yet been proposed to improve the negative effects

caused by massive numbers of independent high-rise buildings.

The concept of “grouped high-rise” arises at this moment. The so called “Sky city” contains groups of high-rise buildings connected by multiple platforms (Figure 4).

## II. Dream and Pursuit of Many Architects and Entrepreneurs

The concept of “sky city” has been inspiring many architects and entrepreneurs in their career paths, among which Arata Isozaki was one of the first few pioneers. In the 1960s, he suggested to construct a “sky network” on existing street blocks, mimicking the form of a forest, in which the “tree trunks” were roads connecting lands, tree branches provided horizontal connections and leaves were considered as residential units.

Mr. Feng Lun of Wan Tong Group proposed the concept of “3D city” in Copenhagen in 2009 and has carried out several schematic designs in Chengdu and Xi’an. His strategy involves several key factors: vertical development, systematic density for structuring of land, unified area of living and manufacturing, intensive exploitation

• 舒适度不够。在地下全靠人工通风采光，终不如在地面上和阳光大气直接接触更自然和谐。

相比之下，**向天借地**，无论从经济、生态、舒适度各方面都更为理想，因而高层建筑群的出现有其必然性。但随着大量高层建筑的建造，大都市成了混凝土森林，人们开始对其厌恶：效率低，能耗大，消防难保障，不接地气，人际关系孤独冷漠。建筑师和政府官员已经意识到这些问题并开始在设计上进行改进，例如避难层的设置，绿化平台以及大楼间加上连廊等，做了诸多改进。然而，对于大量孤立的高层建筑所产生的负面影响并没有一个全面的解决方案。

群体高层天空城市的构想因此应运而生。它的基本概念是一座由成组的多栋高层建筑通过多个平台连结在一起所形成的空中城镇（图4）。

## 二、众多建筑师和企业家的理想和追求

空中城市的构想，或称立体城市、垂直城市、三维城市、紧密城市，是众多建筑师和企业家的理想和追求。较早提出的有日本建筑师矶崎新。他在上世纪六十年代初，构思在现存街区上，构筑树林般的空



Figure 4. Birds-eye view of the “Sky City” (Source: Jiang Architects & Engineers)  
图4. “天空城市”的鸟瞰图（来源：上海江欢成建筑设计有限公司）

of resources, green transportation, and intelligent management.

Mr. Zhangyue of Broad Group, announced to build the world's tallest building, at 838m, in Changsha, which is a non-vehicular sky city with a population over 200,000.

However, Arata Isozaki's idea was perceived as merely science fiction. The project at Changsha has been suspended, as were the ones in Chengdu and Xi'an. Most "sky city" projects appeared to be a flash in the pan. This concept is stuck in a Utopian fantasy and has even become a negative and widely criticized term.

Under these circumstances, why do we still bring up this topic? We consider that the current urbanization development of China is not on a sustainable path. As architects and engineers, we shall do something about it. Although the concept at this stage is far from mature, we hope it could be the stone that raises a thousand ripples.

### III. "Three Bottlenecks" of High-Rise Building

Arata Isozaki's "sky city" was born in the 1960s; the construction technologies and the life styles are nothing like of the present. In addition, his model seemed to have abandoned almost every modern code in existence. Mr. Feng Lun is mainly focusing on fundraising and what goes in the buildings. Although he mentioned grouped high-rise construction, the method is nothing different from our common practice; hence it cannot escape from those inherited disadvantages. Mr. Zhang Yue is concentrating on rapid construction and prefabrication. Though his tower is in an extensive scale, it still falls in a traditional system.

However, this paper is trying to present a completely innovative exploration and seeks a breakthrough on building systems by addressing the following three issues which are staggering modern high-rise construction:

- Low efficiency, large energy consumption. High-rise buildings usually adopt the system of core and external columns, of which core takes up 25–30% of usable area. Plus, elevator operation is unevenly distributed. People queue during rush hour and lunchtime, while the rest of the time elevators are mostly empty.

- Difficulty in fire protection and evacuation. The tragedy that occurred on November 15, 2010 in Shanghai with a residential Building on Jiaozhou Road was a bloody illustration of what fire can do to a high-rise building. The fire spread rapidly upwards and became too high for hoses to reach. Residents were unable to escape downwards and helicopters could not land on roof for rescue.
- Distance from the ground and low comfortability; enclosed space; and isolated relationships between humans, and humans and nature impact high-rise livability.

### IV. Three Core Technologies:

To tackle the above issues, we developed this "Sky City - Grouped High-Rise" concept. In plain words, it is to bundle several super high-rise towers together to form an integrated super high-rise cluster which has one million or even more square meters of built area and offers space for more than 100,000 people, functioning just like a small town.

This concept differentiates itself from the predecessors by the three core strategies:

- Dividing the High-rise buildings into multi-story buildings
- Forming a central core that could be constructed as municipal infrastructure
- Applying a mega-framed structure system

#### Dividing the high-rise buildings into multi-story buildings

At every 15–20 floors, thick platforms are to be constructed to connect the high-rise towers (the interval refers to the current national codes for refuge floors). Each platform is large and strong enough to be considered as the ultimate safety for evacuation. Appropriate firefighting facilities shall be installed on the platform, such as movable water guns and water drenchers. Hopefully the section of the super high-rise tower that sits in between the 2 platforms could be considered as multi-story buildings in the future in terms of fire safety code. In case of a fire, residents shall simply be evacuated to the platform as if reaching a safe zone.

A 3–4 meter wide ledge is designed to be installed along the surface of the high-rise tower at the location where the platforms are.

中网络, 树干是与地面相接的道路等设施, 树枝负责横向连接, 树叶则为住宅单元。

我国万通集团冯仑在2009年就在哥本哈根提出“立体城市”构想, 并在成都西安等地做过一些方案设计。他的想法是: 竖向发展, 大疏大密; 居住和生产一体, 资源集约, 绿色交通, 以及智能化管理。

远大集团的张跃, 要在长沙建设838米的世界第一高楼, 它是一座20万人的无汽车的天空城市。

然而, 矶崎新的天空城市被称为科幻故事, 长沙的高楼停摆, 成都西安的立体城市也被搁浅。许多空中城市只是热闹一阵子, 构想仍停留在乌托邦的科幻之中, 天空城市似乎成为贬义词, 获得诸多诟病。

在这种情况下, 为什么还要提出这个观念? 我们觉得现在中国的城市发展实在不是在可持续的道路上, 作为建筑师和工程师, 我们有责任进行一些探索, 虽然目前的想法远未成熟, 希望能够成为激起千层浪的那块石头。

### 三、高层建筑的三大瓶颈

矶崎新的天空城市出于上世纪六十年代, 当时的建造技术, 生活方式和现在不可同日而语, 而且他的想法几乎完全抛离了现实规范。冯仑的想法集中于如何集资和建筑内容, 虽然也提到了群组大楼的建设, 但组群中单体塔楼仍基于目前的常规做法, 没能解决常规的弊端。张跃的想法集中在如何快速建造, 和预制化生产方面, 塔楼规模虽大, 但体系仍是传统的。

而这里想介绍的是对超高层建筑体系的一种全新探索, 从建筑体系上寻找突破口, 希望从目前高层建筑的三个难点着手:

- 效率低, 耗能大。  
目前常用的高层建筑结构, 是核心筒+外框柱, 其中核心筒占用了25~30%的使用面积, 此其一。其二是电梯忙闲不均, 上下班及吃饭时间排队等电梯, 而业务时间则很空。
- 消防避难、安全疏散困难  
典型的事例是2010年11月15日上海胶州路住宅大火, 火势延外墙毫无阻挡地向上蔓延, 地面水枪够不到, 人无法向下逃生, 就算向上逃到屋顶, 直升机也无法降落。
- 舒适度差, 不接地气。封闭的空间; 人与人、人与自然之间的孤立。





Figure 5. "Sky City" garden platform (Source: Jiang Architects & Engineers)  
图5. “天空城市”花园平台（来源：上海江欢成建筑设计有限公司）

These ledges plus some built-in firefighting facilities could effectively prevent the fire from spreading between each platform.

The platform also serves as a sky garden (Figure 5). Each platform could extend up to 100m wide, large enough to match a park on the ground. Residents and workers living in the towers can easily get access to the platform, to socialize, to relax, and even to develop some organic farming here. Towers that support the platforms are standing far enough from each other to provide enough natural daylight to the platforms. As the platforms are constructed far away from the ground, air quality shall also be improved.

The platform itself shall be constructed as a hollow structure of 2–3 levels deep. The internal space could be used for public facilities, such as a hospital, school, theater, shopping mall, offices, plant rooms or even light manufacturing. Therefore, each section of this mega-sky-city works just like a multi-functioned street block, which provides all necessary facilities and job opportunities. Since part of it is housing, a portion of its residents shall be able to work close to home

#### 四、三大核心技术

针对上述问题，我们构想了“天空城市-群体高层”的概念，讲白了就是将多栋超高层建筑捆绑在一起，形成一个整体化的超高层组合体，组合体可能拥有上百万平方米面积，数以十万计的居民，具备一个小城镇所有的功能空间，宛若一座超高城市。

这个天空城市不同于以往其他概念的地方在于三大核心策略：

- 高层建筑多层化
- 竖向设施市政化
- 结构巨型框架化

#### 高层建筑多层化。

每十五到二十层左右建一个巨型平台，将高层建筑组之间相连（参照目前高层建筑避难层设置规范）。每个平台足够大且坚固，大到可作为消防疏散的安全平台，通过增加适当的消防设施，比如平台上的移动式消防水炮或水幕。我们希望在将来这样平台之间的楼层在消防规范上可被视为多层建筑，从多层建筑内跑到平台上，就到达了安全地带。

在平台所在的超高层塔楼的外皮上，我们挑出了一圈3–4米宽的檐口，遇局部的火警，这些宽檐口和内藏的消防设施可以有效地阻断火势的上下蔓延。

平台同时可以作为空中花园（图5）。由于平台平面尺寸可以达到百米左右，其实和地上的公园有的一比。塔楼居民或者上班族都可以方便地来到这里，在此休憩和活动，甚至开展有机农业。周围塔楼的间距有足够的间距使阳光照到空中花园，由于远离地面，相信空气质量也会提高。

平台本身是个两三层高的空心结构，其内部空间可用作公共设施如医院、学校、幼托、剧场、商场、办公、设备层以及轻型的生产空间等，这样两个平台及其之间的楼层就如同地面的一个多功能街区（mixed use development），拥有各种配套设施，同样也能提供各种就业机会，同时又是居住社区，这样相当大一部分的居民可以就近生活生产，节约出行时间，减轻城市地面交通压力。平台上以步行为主，辅于小的电瓶车运输，确保人们生活的平静和安全（图6、7）。

形象点来说，这个概念有如把上海东西向的南京路、北京路、福州路乃至延安路等主干道竖立起来，而让南北向的河南路、西藏路、成都路、江宁路、万航渡路成为空中花园，里弄则分布在花园之中。

#### 竖向设施市政化。

这项策略旨在提高楼层的使用率以及垂直交通的使用率。

高层建筑的核心筒内主要是电梯楼梯和设备管线。通常楼越高，核心筒所占面积越大，实用率越低。既然在第一项技术里，我们将高层建筑隔成多个多层，我们就可以把原先核心筒内的很大一部分设施从单个大楼中剥离出来，集合在平台的中心位置，形成集约化的高速电梯和市政设施主干，其结果，必将大大减少核心筒面积并提高其楼层使用率。



Figure 6. "Sky City" ground view (Source: Jiang Architects & Engineers)  
图6. “天空城市”人视图（来源：上海江欢成建筑设计有限公司）



Figure 7. Park view of the "Sky City" (Source: Jiang Architects & Engineers)  
图7. “天空城市”公园景（来源：上海江欢成建筑设计有限公司）



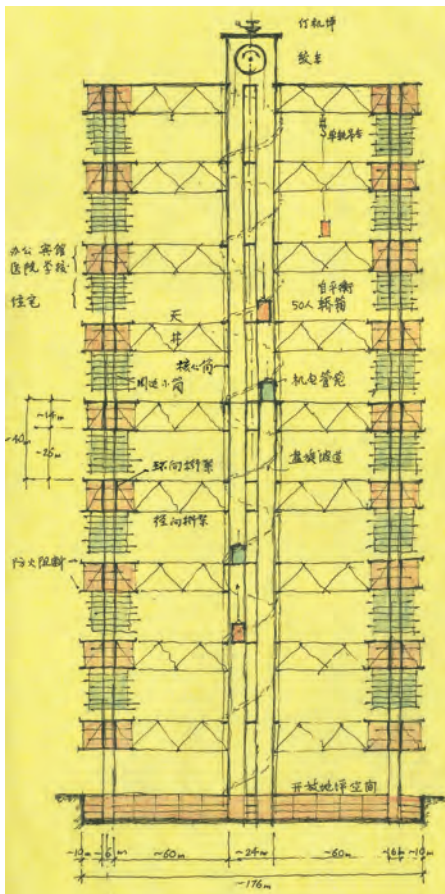


Figure 8. "Sky City" section diagram (Source: Jiang Architects & Engineers)  
图8. "天空城市"剖面概念草图 (来源: 上海江欢成建筑设计有限公司)

and save significant travel time, which helps to relieve traffic on the ground. The surface of the platform is a pedestrian zone, a safe and peaceful sky garden. People can also move around by golf carts (Figures 6 & 7).

A creative expression of this idea could be illustrated as a vertically erected Nanjing Road, Beijing Road, Fuzhou Road and Yan'an Road, horizontally extending Henan Road, Xizang Road, Chengdu Road, Jiangning Road and Wanhangu Road as platforms of gardens. Small lanes are scattered among the gardens.

**Forming a central core that could be constructed as municipal infrastructure**  
This strategy aims to improve the usable floor area of buildings and efficiency of the vertical transportation.

In normal high-rises, cores are usually comprised of elevators, staircases and pipe ducts. Experience told us that a taller building requires larger core area. Since we've cut the super high-rises into multi-story buildings by our first strategy, we could then extract large amounts of equipment from the previous cores and bundle them at the center of each platform to build an integrated spine with high-speed high-capacity elevators and utility mains, which will significantly reduce the core area and improve the floor efficiency.

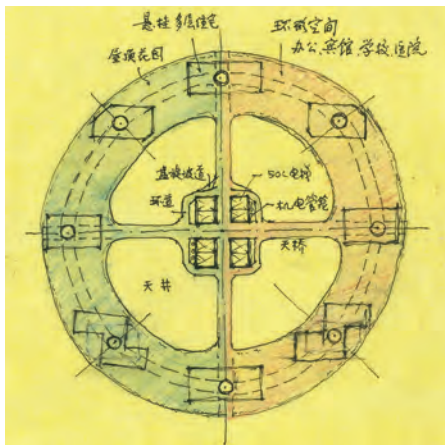


Figure 9. "Sky City" plan diagram (Source: Jiang Architects & Engineers)  
图9. "天空城市"平面概念草图 (来源: 上海江欢成建筑设计有限公司)

One of the key ideas of this strategy is that the construction of this spine should be paid by the government, who is paying for the municipal roads and utility mains anyway while developing low-rise communities.

In the spine, elevators shall be designed as public buses which stop at each platform. Within each high-rise surrounding the platform, small elevators and stairs are considered as mini buses and provide micro-systems vertical circulation. If the whole project is constructed on top of a metro station, one could directly access the sky city by transferring to vertical transportation (Figures 8 & 9).

**Applying Mega Framed structure**  
Most people believe that the bottleneck of high-rise construction exists in structural engineering. I do recognize structure being an important factor in high-rise construction. It undertakes massive loading, wind and earthquake loads, which are critical to building safety. However, with the development of materials and structural technologies, it is not a restraining factor to the high-rise construction as it used to be. The tallest building which has been completed is the Burj Khalifa in Dubai, which reaches 828m. JAE has also proposed the design for the Shanghai Centre tower which is 750m tall along with a solar energy tower of 1000m tall. With good site conditions (such as rocks or a thick sand layer), reasonable building height to width ratio (i.e., 6:1), and advanced technologies and rational selection of structural shape and material, it is possible to bring the building height over a thousand meters.

For this "sky city," we want to apply a fundamentally different structural system from normal high-rises. We call it the Mega Frame system (Figures 10 & 11). In this system, the towers no longer work for themselves; they become members of the mega frame. They work together with the connecting platforms

此策略的关键在于希望这条主干由政府买单。因为建设多层社区时,市政道路以及其下方的管线由政府建设,那为什么同样是公共的垂直道路和市政管道就不行?

垂直运行的电梯仿照公交系统进行设计,高速电梯犹如公交大站车,停靠点就是每个大平台,而在平台周围的“多层建筑”中,则设小电梯和楼梯,犹如穿梭小巴,作垂直交通的微循环。如果它座落在地铁上盖,人们不出地铁,就可以转乘垂直公交直上天空城市(图8、9)。

**结构巨型框架化**  
人们多认为高层建筑的瓶颈在于结构。作为一位结构工程师,我认为结构之于高层建筑确实重要,它承担着巨大的负重和风力地震的荷载,对建筑安全起着至关重要的作用。但随着建筑材料以及结构技术的进步,它不再起制约作用。现在已建成的最高建筑迪拜塔高828m, JAE公司也曾经尝试过750m高的上海中心大厦方

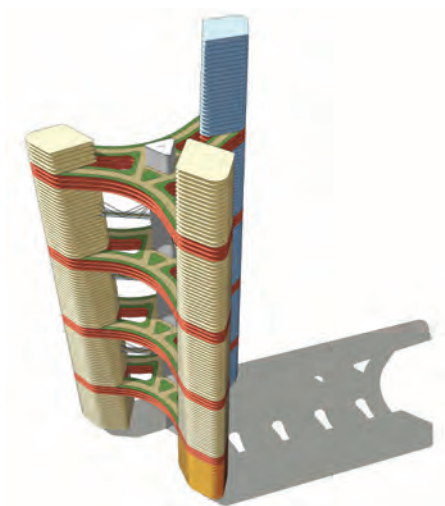


Figure 10. "Sky City" function allocation (Source: Jiang Architects & Engineers)  
图10. "天空城市"功能分布 (来源: 上海江欢成建筑设计有限公司)

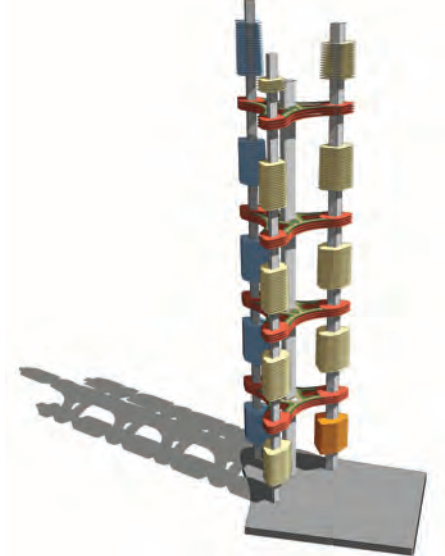


Figure 11. "Sky City" composition diagram (Source: Jiang Architects & Engineers)  
图11. "天空城市"构成分析 (来源: 上海江欢成建筑设计有限公司)

	Area (m2) 面积 (平米)	Construction cost with current design (yuan) 目前单价 (元)	Construction cost with sky city design (yuan) 天空城市单价 (元)
High-rise residential/apartments 高层住宅 / 公寓	145,000	5,000	8,000
High-rise hotel   高层酒店	60,500	9,000	12,500
Super high-rise office   超高层办公	116,600	10,000	11,500
High-rise office   高层办公	114,000	7,000	11,500
Retail podium   商业裙房	56,000	4,500	11,500
Basement retail   地下商业	170,000	6,000	6,000
Basement car park   地下车库	247,000	3,000	3,500
Total CFA   总建造面积	1,164,500		
Total Construction Cost   总造价		4.646 billion   46.46 亿	7.100 billion   71.00 亿
	Site Area   建设用地	266 acre x 20million/acre = 5.32 billion 266亩 x 2000万元 / 亩 = 53.2 亿	90 acre x 20 million/acre = 1.8 billion 90 亩 x 2000万元 / 亩 = 18 亿
	Total Investment   总投资	9.97 billion   99.7 亿	8.90 billion   89.00 亿

Figure 12. caption (Source: Jiang Architects & Engineers)  
图12. caption (来源: 上海江欢成建筑设计有限公司)

as a whole system. Plus with a mega trusses and damper system, the system is much more stable and ductile in terms of resisting wind and earthquake loads.

### V. Financial Solution of the Sky City

There is a massive mixed-use development undergoing development in Shanghai. Its site consists of 4 street blocks and has a total site area of 266 Chinese acres. The total CFA of the development is around 1.16 million square meters; it has office towers, residential towers, apartments, hotels, shopping streets, underground retails, and carparks, etc. We did a trial redesign using this project as a subject of study. We tried to fit everything into a “sky city” which occupies only 1/3 of its original site.

Based on the trial design, we did a cost comparison between the two as follows (Figure 12):

The above investment does not include financial cost and a lot of other costs. It does not take into account the land compensation fee that the government might ask the developer to pay. It does not include the cost of the central spine which might be compensated by the government.

Nevertheless, thanks to the much smaller land acquisition cost, it seems clear that the sky city is not more expensive than the normal development as we would have thought so. By doing a development in this way, a lot of land can be saved for public green space. Since the platforms are elevated from the ground, it gives back 80% of its site area back to the city. The social benefit so achieved is priceless.

Another important message we got from this study is that the more expensive the site is, a better fit for this type of sky city development. By the calculation, we found out that once the land value goes under 14 million RMB/acre, A sky city would become more expensive than the normal development. Hence, city centers of a metropolitan city are the ideal locations for the sky city development.

### VI. Further Research on “Sky City - Grouped High-Rises”

This sky city proposal is at its infant stage. It requires collaboration of a lot of different parties: the government, planners, designers, engineers and even scientists. It raises many challenges and provided many opportunities for innovation at the same time. The following is a list of subjects that we think might be relative to this topic:

- Psychology – human beings’ adaption towards height;
- Sociology – building management, realization of a harmonious community;
- Urban planning – land bearing capacity and rational layout of infrastructure
- Architecture – optimization on daylights and ventilation; superposition of different building plans;
- Structure – ductility of mega structure; application of high-strength and high-efficiency structure; wind resisting, seismic resisting and protective measures of blast impact;

案，及1000m高的太阳塔的方案设计。只要有较好的地基条件（如较厚的砂层或岩石），并掌握恰当的建筑物高宽比（如6：1左右），采用先进的技术及结构选型，造逾千米高的建筑是有可能的。

本人设想群体高层天空城市主体结构较好的结构型式，是完全不同于传统高层建筑的带阻尼装置的巨型框架或带阻尼装置的巨型桁架（图10、11）。在这个结构体系中，塔楼不再是单独的，而是结构框架中的一部分。一个高层建筑群和联系大平台一起工作，形成巨型结构体，尤其有利于抗风和抵抗地震力。

### 五、天空城市的经济账

我们以上海某城市副中心的现有设计为例，进行了群体高层天空城市的试设计。原设计占了4个街区，266 亩地， 地上地下总共116万平米的建筑面积， 其中包含集中商业，酒店，住宅，办公，公寓，停车等各种功能。我们的试设计尝试只用现有基地的三分之一来容纳所有原有面积和功能。

下表是我们按两种情形做的估算比较（图12）：

当然上述总投资不包括金融成本等诸多其他费用，也没有考虑政府要求补地价的情况，也没有考虑政府可能出资的核心筒造价。

但由于地价的因素，粗略看来天空城市似乎并不比一般的开发贵。但这样的开发让出大量的地面做成片集中绿化，并且建筑群本身也是架空的，因而可以说80%的地面都还给了市民。这样的社会效益是不可估量的。

上面的表格还给出另一个信息，地价越贵，越适合这类项目。经测算，当地价低于1430万元 / 亩时，上述项目的总投资便会高于一般性的开发。所以此类项目最适合在大中城市的市中心。

### 六、“天空城市-群体高层”建设的研究课题

群体高层天空城市，目前还是个非常不成熟的概念。它必须整合各种资源进行理念创新、科技创新的产物，它为政府规划机构、规范编制机构、设计人员、科技人员提出了很多问题，也提供了硕大的创新空间。以下大致罗列了需要综合研究的若干问题。

- 心理学——人们住超高层的心理适应能力

- Mechanical – sectional water and power supply; high speed elevator;
- Landscape – garden and agricultural plants under various temperatures and air qualities
- Transportation – connection with ground and metro station; interconnection between above and below; emergency measures;
- Materials – application of high performance, light and high efficient materials;
- Fire protection – cantilevered platform; fire durability;
- Sustainability – utilization of solar and wind energy; rainwater collection
- Internet Plus – application and development of IT industry in buildings
- Economics – additional unit construction cost; analysis on the beneficial effects on land, transportation, etc.

## Ending

During the study, a beautiful picture of the future city seemed to be gradually unfolding in front of us: several sky cities rise high into the cloud; many people live, work and having fun in them whilst the trees extend up into the towers from ground (Figure 13). In between the towers, there are large area of green space, and the old urban fabric can still been seen among the greens. Cars and public transportations are running much more smoothly between the cities. They are mostly electric driven.



Figure 13. City view of the "Sky City" (Source: Jiang Architects & Engineers)

图13. “天空城市”城市景（来源：上海江欢成建筑设计有限公司）

- 社会学——大厦管理，和谐社区的实现
- 城市规划——土地的承载力，基础设施的新布局
- 建筑——日照通风的优化设计，如何将不同类型的建筑平面叠加在一起
- 结构——巨型结构的延性；高强、高效结构的应用；防风、抗震、防恐防暴
- 机电——超高层分段式供水供电，高速大型电梯、
- 园林景观——在不同高度的气温、空气质量下的植被、作物
- 交通——和地面、地铁交通的连接，上下内部连接及应急措施
- 材料——高性能、轻质高效材料的应用
- 消防——平台外伸长度，耐火要求
- 节能——高空太阳能风能的利用，雨水收集
- 互联网+——IT产业在大厦中的开发应用
- 造价——单体建筑增加费用，土地、交通，获得的效益分析研究

## 结束语

在研究的过程中，我们似乎看到了这么一副美好的图景：高耸如云的天空城市上绿意盎然，人们在里面生活、工作、休闲、娱乐（图13）。天空城市塔楼之间的原有城市地面充满了绿色，较低的建筑和小街小巷仍然保留着，掩映在绿树丛中。公共交通便利了很多，其中大多都是电动。