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Engineering Contractor Management
工程总承包管理

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Megatall high-rise projects face difficulties that require innovative solutions in terms of material coordination, allocation of labor resources, large massing, complex multi-system engineering, noise control, net height control, multi-process coordinated construction, processing venue restriction, and more. To explore these solutions, a unique organizational management approach was adopted. Firstly, it established progressive management concepts that relied on new technologies (e.g. logistics shipping management, factory based pre-manufacturing, on-site assembly, BIM modeling, cloud network coordination, CFD data simulation, etc.). Furthermore, advanced technical approaches were used, along with the establishment of a lean construction method that utilized technological solutions. This chapter addresses the difficulties faced by project administrators for the Ping An Finance Center and provides an overview of the identified solutions from a project management perspective.

平安金融中心是具有独特建筑结构的超高层国际甲级写字楼，目前国内超高层建筑物工程施工的特点和遭遇的实际困难具有共性问题，在工程施工中都面临物料的垂直运输统筹，劳动力资源的调配，复杂的大体量、多系统的机电工程深化设计，噪音控制，净高控制，多工序协调施工，加工场地限制等需要解决的难题。在超高层建筑工程施工项目管理和技术创新应用方面进行一些尝试性的实践和探索，采用独特的组织管理、创立新颖的管理理念及新科技的结合应用 (如物流化运输管理、工厂化预制—现场装配化施工、BIM模型、云网络协同、CFD数值模拟等)，应用先进科技手段和措施以及竖立精益建造、技术建造的思想，来解决超高层建筑项目施工管理面临的难题，形成示范作用并提升项目管理品质和施工技术水平，实现项目的管理目标。

Project Scale

The scope of engineering contracting for the Ping An Finance Center includes: advanced electric engineering (substation and distribution system, dynamic lighting power distribution, lightning protection and grounding, civil defense and electrics), electronic engineering, and HVAC engineering.

Technical coordination includes disciplines such as fire protection, electronics, floodlighting, plumbing, and other sub-contracting projects.

MEP Construction Schedule

- February 27, 2013 comes into play
- completed in March 12, 2016 the combined mechanical and electrical debugging
- completed in April 16, 2016 and passed the acceptance
- completed in June 23, 2016

Project Management Pattern

General contract + self operation + sub-contract + technical coordination (see Table 5.1)

项目规模

机电总承包包括: 强电工程 (变配电系统、动力照明配电、防雷及接地、人防电气)、弱电工程、通风空调工程。

技术协调: 消防专业、弱电类专业、泛光照明专业、给排水等分包工程。

工期进度

- 2013年2月27日进场
- 2016年3月12日完成机电联合调试
- 2016年4月16日完工并通过验收
- 2016年6月23日竣工

项目管理模式

总承包+自营+分包+技术协调 (请详见表5.1)

Project Organization Structure and Team Setup

Project Organizational Structure

Figure 5.10 shows the adopted four-tier management structure that includes a corporate assurance monitoring section, an engineering general contract management section, a construction administration section, and a construction section.

Setup of Engineering General Contract Management Section

There are 11 departments in total that comprise the general contract management system: Engineering General Contract Coordination Department, Planning & Management Department,

项目组织架构与团队设置

项目管理架构

设置四级管理机构 (包括企业保障监督层、机电总包管理层、施工管理层、施工作业层) (请详见附图5.10) 。

机电总承包管理层设置

机电总包协调部、计划管理部、深化设计中心、BIM工作站、科技研发部、物资管理部、商务管理部、工程管理部、质量管理部、安全管理部、综合办等11个部门。

Design Development Center, BIM Workstation, Technical R&D Department, Material Management Department, Business Management Department, Construction Administration Department, Quality Management Department, Safety Management Department, and the General Office. To identify the duties of personnel in charge of major management departments, an engineering sub-contract management department, a phased and regional coordination management team, a design development, a BIM management, an engineering and commissioning department, and a safe environment management department were established.

Project Organizational Structure Diagram and Management Duties

In order to ensure the achievement of the project's management goals, the Engineering General Contract Department has identified the following management duties:

- To be responsible for the control and management of the overall safety, quality, and progress of engineering projects
- To be responsible for the review of design development progress including the planning of all engineering related disciplines. Furthermore, to review design development drawing quality, initiate and organize comprehensive engineering piping design, and to promote design development utilizing BIM models.
- To be responsible for organizing construction design review and specialized construction program review within its scope of management
- To be responsible for the organization and coordination of all engineering related disciplines
- To be responsible for organizing and participating in various engineering production meetings and to convene regular engineering general contractor coordination sessions

确定主要管理部门即机电分包管理团队负责人、分段分区域统筹协调管理团队负责人、深化设计负责人、BIM管理负责人、机电调试负责人、安全环境管理负责人的职责。

项目组织机构图及管理职责

为保障项目管理目标的实现，机电总承包部确立了如下管理职责：

- 负责机电工程总体安全、质量、进度的控制和管理
- 负责机电各专业深化设计进度计划审核、深化设计图纸质量审核、牵头组织机电综合管线深化设计、运用BIM 模型辅助深化设计
- 负责其管理范围内的施工组织设计审核、专业施工方案审核
- 负责机电各专业工程的组织协调工作
- 负责组织、参加机电工程各类生产会议，定期组织召开机电工程总承包协调例会

超高层项目的建造理念

在加强管理明确责任的同时竖立精益建造、技术建造技术建造的理念，充分发掘科技应用新思路，应用BIM技术的创新手段提升建筑业项目的管理品质。

从项目的管理实践中总结和探索建筑行业发展的新途径，行业要发展首先应当起源于理念的创新，即新思路、新思维、新概念; 然后推进到项目的管理生产活动中，产生新的管理组织流程; 再者推动行业新技术的应用和发展。

通过BIM模型的建立，运用项目的预可视化。运用进度模拟、碰撞报告、工厂化预制等手段，减少物料的消耗，提高质量、提高工艺效率、减少浪费。

发展技术建造，运用各种新科技服务于项目施工，例如机器人全站仪与BIM模型的结合应用、二维码的物流管理系统、BIM模型的多种模拟应用等。

创新机电施工管理

由于超高层机电系统复杂、设备及管道规格大(或容量大)、机房数量众多，对施工组织能力和工艺操作能力要求高。机房和主干管道较为集中，系统分级清楚，建筑功能分区很明确。根据施工流程和施工工艺的要求，采取分段施工的办法组织施工，以满足总

1	Progress target 工期目标	Project completion by June 23, 2016 竣工日期为2016年6月23日
2	Quality target 质量目标	To win National Quality Project Award, Lu Ban Award, Zhan Tianyou Award 获得国家优质工程奖、鲁班奖、詹天佑奖
3	Safe and civilized construction 安全文明施工	Shenzhen-Guangdong dual level safe and civilized quality construction site 深圳市、广东省两级安全文明双优工地
4	Sustainable development target 可持续性发展目标	LEED Gold certification 美国绿色建筑协会LEED金级认证
5	Service target 服务目标	Whole course construction management, 100% coordinated service coverage 工程施工全过程管理、协调服务履盖100%
6	Information target 信息目标	Delivery of complete BIM completion model 完整BIM竣工模型的交付

Table 5.1. Project management objective(Source: Tiejun Tang)
表 5.1.项目的管理目标 (出自: 唐铁军)

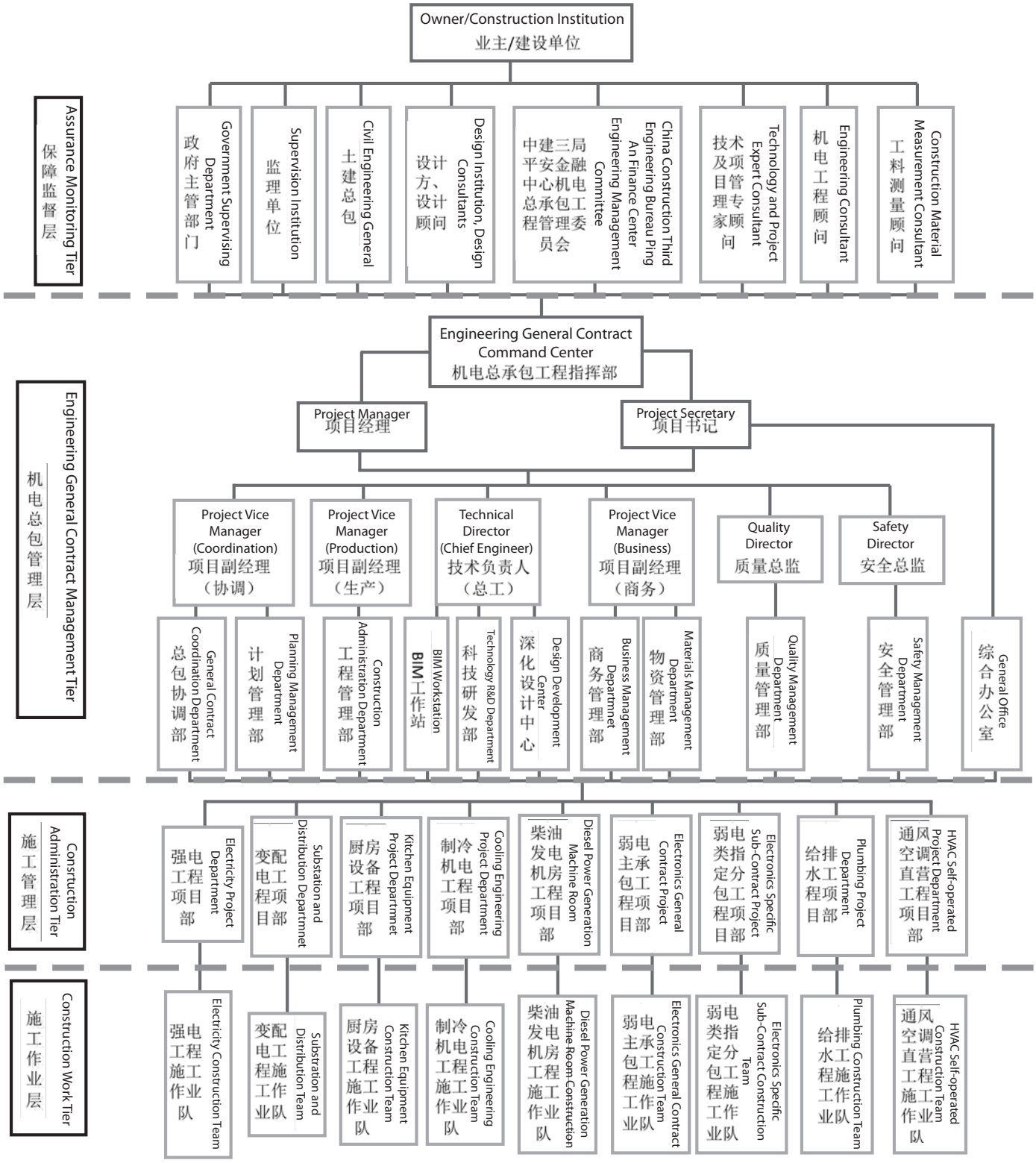

Figure 5.10. Ping An financial center electrical contracting organization chart. (Source: Tiejun Tang)
图5.10. 平安金融中心机电总承包组织机构图 (出自: 唐铁军)

Construction Concept of Supertall Projects

Concepts supporting lean and technological construction are established in order to fully explore new ideas for technological application and raise the management quality of architectural projects by applying innovative approaches incorporating BIM technology.

New development methods for the construction industry are summarized and explored from the project management practice. The development of any industry should identify innovative concepts, i.e., new mindsets, new ideas, new concepts; and incorporate them into management and production activities, generating new management processes, and using them to drive the application and development of new technologies in the industry.

体施工进度计划的需要，并且不断创新和完善管理组织流程以及科技创新，达到专业化、高效率的施工目的。

始终贯彻统筹组织、协调服务、集成管理的管理思路（请详见附图5.11）。

超高层设备材料的垂直运输的组织管理

建立专业的运输团队，统筹组织安排，做到专业、统一、高效、有序管理，及时的配送。

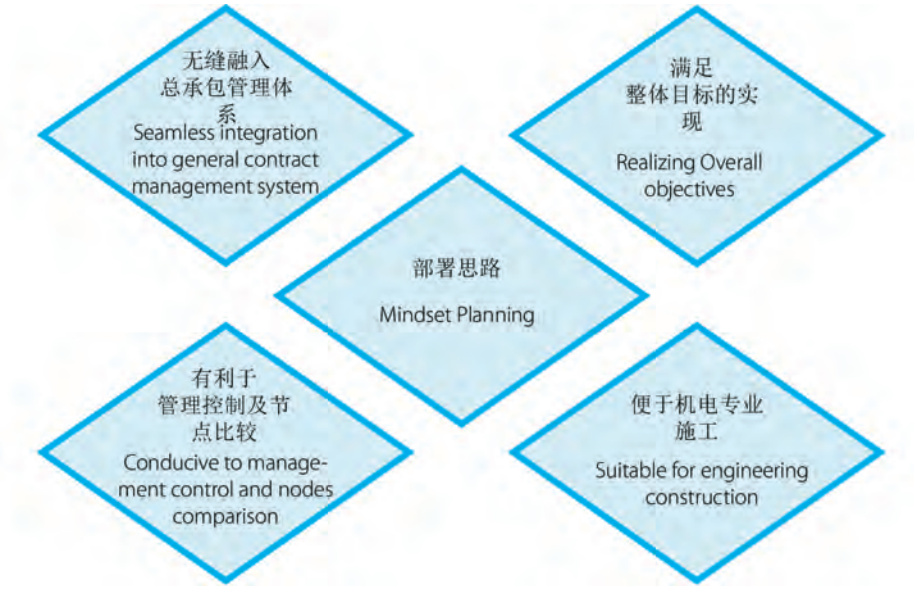

Figure 5.11. Overall Strategic Thinking (Source: Jian Zhong)
图5.11. 总体策划思路 (出自: 钟剑)

For instance, Ping An Center utilized pre-visualization through the establishment of BIM models. Using simulations, collision test reports, and factory based pre-manufacturing, the goals of reducing material consumption, increasing quality, and raising process efficiency are achieved.

Innovation also lies in developing technological construction methods. Various new technical services need to be incorporated into construction, (e.g. combined application of robot total station and BIM models, two-dimensional code logistics management system, multiple simulated applications of BIM models, etc.).

Innovative Engineering Construction Administration

Considering the complexity of the engineering systems in super high-rise buildings, the large specifications (or large capacity) of equipment and piping, and the large quantity of machine rooms, a higher requirement is set for construction organization and process operation capacity. The machine room and main piping are comparatively concentrated, system hierarchies are clear, and the building's functional zoning is well defined. Construction should be organized by adopting a phased approach based on the requirements for construction processes and techniques so as to meet the requirements of the construction schedule. Moreover, continued improvement of management processes and technological innovations are required to achieve highly efficient construction.

The management concept of coordinated organization, coordinated service, and integrated management should be consistently implemented (see Figure 5.11).

Organization and Management of Vertical Shipping for Supertall Equipment and Material

Professional shipping teams should be put in place to achieve professional, efficient, orderly, and timely deliveries.

Our team also gathered data and analyzed the weight of various engineering materials, selected shipping methods and numbers of shipping trips based on site conditions, and prepared the shipping timeframes of various materials based on overall progress. Two-dimensional codes and RFID technologies are introduced for logistics management to facilitate tracing and inquiry. 15% of vertical shipping for small-sized materials can be shared by localized vertical transit shipping through dual-track suspended cage set up at ventilation shafts.

Work Method Arrangement of Megatall Operation

1. Difficulties in personnel and materials transport can be alleviated with organized, well planned, and reasonable arrangements of two-shift or three-shift work teams during construction rush hours.
2. The limited capacity of elevators in super high-rise building construction results in prolonged journeys and over-crowded rides during rush hours, which is not conducive to workers' lunch breaks and can cause difficulties with dining. To

统计并分析了各类机电材料的重量，结合现场状况选择运输方式、运输次数，并结合总进度编制了各类材料的运输时间段。引进二维码和RFID技术进行物流化运输管理，方便追踪查询。通过设置在通风管道井的双轨式吊笼进行局部垂直转运，可以分担15%小件材料的垂直运输工作。

超高层劳动力的作业形态安排

1. 施工班组在施工高峰和抢工期间有组织、有计划地合理安排作业班组，进行二班制或三班制，缓解人员运输和材料运输困难的问题。
2. 超高层施工由于电梯运力紧张，上下行程时间长，上下班高峰拥挤，不利于工人的午间休息以及用餐。统一安排按时送餐和送水到施工班组的所在楼层。

机电先行的管理理念

- 机房优先: 设备机房是整个机电系统的心脏，对机电的调试和交验起决定作用
- 管井优先: 管井是整个建筑工程的脉络，是机电的主干线，直接影响机电系统的形成和调试
- 调试优先: 在机电某些局部系统基本完成设备安装后，在设备安装后竣工验收之前，即进行优先的单机或局部系统的调试，及早消除缺陷，为下道工序做好准备工作

创新科技的运用

科技创新是企业持续发展的必由之路，产生更多的新标准、新专利，提高企业发展的核心竞争力。

二维码与物流化配送

采取物联网信息管理技术高效地管理现

organize synchronized meal and water delivery to the floors, the construction team operates at set hours.

Management Concept of Prioritized Engineering

- Prioritized machine room concept: the machine room is the heart of the entire engineering system, which has a deciding effect on the commissioning, delivery, and acceptance
- Prioritized shaft concept: shafts are the veins of the overall construction and the backbone of engineering, which directly affects the formation and commissioning of engineering systems
- Prioritized commissioning concept: prioritized single machine or local system commissioning is to be conducted after substantial completion of equipment installation on certain local engineering systems while prior to final acceptance of construction, so as to eliminate defects at the very beginning, laying a solid groundwork for subsequent procedures

Application of Innovative Technology

Technological innovation is inevitable in the sustainable development of a company, which generates new standards and patents, further increasing the core competitiveness of a company.

Two-Dimensional and Logistics Delivery

To adopt digital information management technology to efficiently manage the materials on site, a two-dimensional code is allocated to each section of piping and each component while BIM generates wind and water piping pre-manufacturing drawings. This establishes an information database platform containing the location, dimension, system location, and purpose of each section of piping and component. Consequently,

Figure 5.12. (a) Two-dimensional code equipment accessories (Source: Tiejun Tang)
图5.12. (a) 设备配件的二维码 (出自: 唐铁军)

Figure 5.12. (b) Two-dimensional code equipment accessories (Source: Tiejun Tang)
图5.12. (b) 设备配件的二维码 (出自: 唐铁军)

场材料，在BIM生成风管、水管预制加工图的同时分配给每节管道、每个部件一个二维码，建立包含了这节管道及部件的位置、尺寸、所在系统及用途等信息数据库平台，保证所有可读取二维码的设备随时读取信息。预制成品出厂、运输、现场验收、安装等环节，项目部可通过物联网管理系统对管道进行全程的跟踪与统计。建立数据库，以方便后期建立物业的运维管理系统（请详见附图5.12a、b、c及d）。

机器人全站仪与BIM模型的结合

应用Trimble VISION强大的可视化工具，在控制器屏幕上用户可以通过点击屏幕的方式快速容易地识别和捕获相关数据。设立专门的测量人员和机构，用全站仪对基准定位点及轴线进行必要复核，根据测量成果反馈编制机电安装测量竣工图及真实BIM竣工模型。经计算机处理可获得BIM模型与现场实际施工的准确误差。高效放样，精确施工。

BIM云网络协同设计工作室

目前我司携手网络科技公司联合打造平安金融中心BIM云平台。

- 通过云计算技术解决因为模型信息量大而导致运行缓慢或无法运行的问题，提高模型深化设计效率
- 保证信息存储的安全性，便于信息的统筹管理
- 减少BIM对计算机硬件设备的依赖

this ensures that all equipments are able to read two-dimensional codes and have access to information at any time. For stages including dispatch, shipping, on-site acceptance and installation of pre-manufactured finished products; the project department can carry out whole course follow-ups and accounting through a "LOT" management system. A database is built to facilitate the operation and maintenance management system of future properties (see Figure 5.12a, b, c and d).

Combination of Robotic Total Stations and BIM Models

The powerful Trimble VISION visualization tool can be used to rapidly and easily capture relevant data by clicking the screen. Dedicated measuring personnel and institutions are put in place to carry out necessary reviews of the benchmark anchor spots and axes by using a total station. Engineering, installation, measurement completion drawing, and BIM completion models are prepared based on measurement results. The specific deviation between the BIM model and the on-site construction can be obtained through computerized processing. Efficient lofting and accurate construction can be guaranteed.

BIM Cloud Network Coordinated Design Studio

Currently, our company is joining forces with internet technology companies to create a BIM cloud platform for Ping An Finance Center for the following reasons:

- to solve the problem of slow or failed operations due to large volumes of information through cloud computing technology increasing the design development efficiency of models;
- to ensure the safety of information storage and facilitating the coordinated management of information;
- to reduce dependence of BIM on computer hardware equipments.

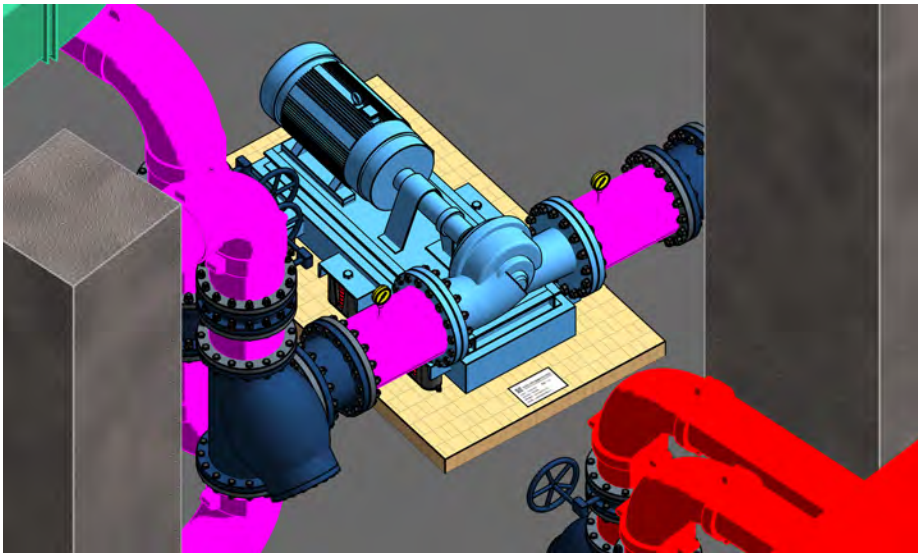

Figure 5.12. (c) Two-dimensional code equipment accessories (Source: Tiejun Tang)
图5.12. (c) 设备配件的二维码 (出自: 唐铁军)

Figure 5.12. (d) Two-dimensional code equipment accessories (Source: Tiejun Tang)
图5.12. (d) 设备配件的二维码 (出自: 唐铁军)

通过建立BIM云计算网络形成一个完整的、高性能、安全建筑设计系统，各专业间形成互联互通、协同高效的工作模式，能及时优化和维护模型（请详见附图5.13a及b）。

BIM工作站在项目的应用

族库与建模 (Revit)

结合厂家产品信息库，运用3ds Max、Revit、Inventor等三维模型软件为本工程的机电系统建立完整的三维数字模型，并配置参数信息全面的各类产品族库，进行专业和综合管线的优化设计，净高标高分析，解决空间碰撞问题。

进度模拟与碰撞报告

应用Navisworks软件，结合现场各项进度计划安排，进行本工程进度计划的模拟和综合管线碰撞。优化施工流程和工期安排，优化综合管线的排布。模拟建造过程，以达到对整个施工过程全程监控的目的。对BIM模型进行二次深化，包括模型构建、碰撞处理措施及最终绘制可施工图纸。

同时将机电工程施工方案及工艺模拟的方法和最优化施工方案以案例形式进行了演示。

运用三维软件绘制系统装配图

利用软件的高精度和自动编码功能，将构件的BIM模型结合数字化构件加工设备，实现预制、预加工构件的数字化精确加工，以保证相应部位的工程质量。

1. 实现工厂化预制、物流化运输、装配化施工
2. 比较预制加工施工与传统施工方法的优缺点，形成成本分析

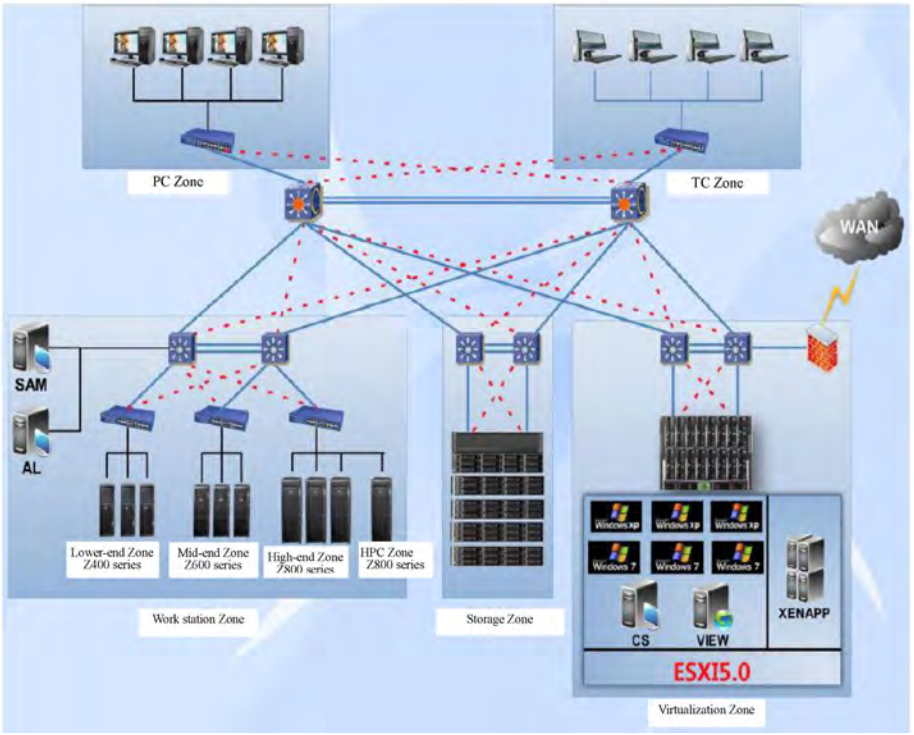

Figure 5.13. (a) Cloud Network System Illustration (Source: Shenzhen xiechuang Tiancheng Technology Co. Ltd.)
图5.13. (a) 云网络系统示意图 (出自: 深圳携创天成科技有限公司)

To create a complete, high performance, and safe architectural design system by establishing a BIM cloud computing network, an inter-connected, coordinated, and efficient work pattern is formed among disciplines, realizing timely optimization and model maintenance (see Figure 5.13a and b).

Application of BIM workstation In Projects

Revit Modeling

In combination with the manufacturer's product information base, we have established a complete 3-D digital model for the engineering system of this project using 3-D modeling software including 3ds Max, Revit, and Inventor. Through the configuration of various products' Revit files, parameters carried out optimized coordination of disciplines and integrated piping and net/standard height analysis, solving spatial collision problems.

Progress Simulation and Collision Report

The simulation of this project's progress plan and integrated piping collision are carried out by using Navisworks software in combination with the various on-site progress schedules. Navisworks organizes the construction process and progress arrangements as well as, optimally organizes the integrated piping systems. The construction process is simulated to achieve the purpose of monitoring of the entirety of the construction process. The second development of BIM models is then carried out including model construction, collision

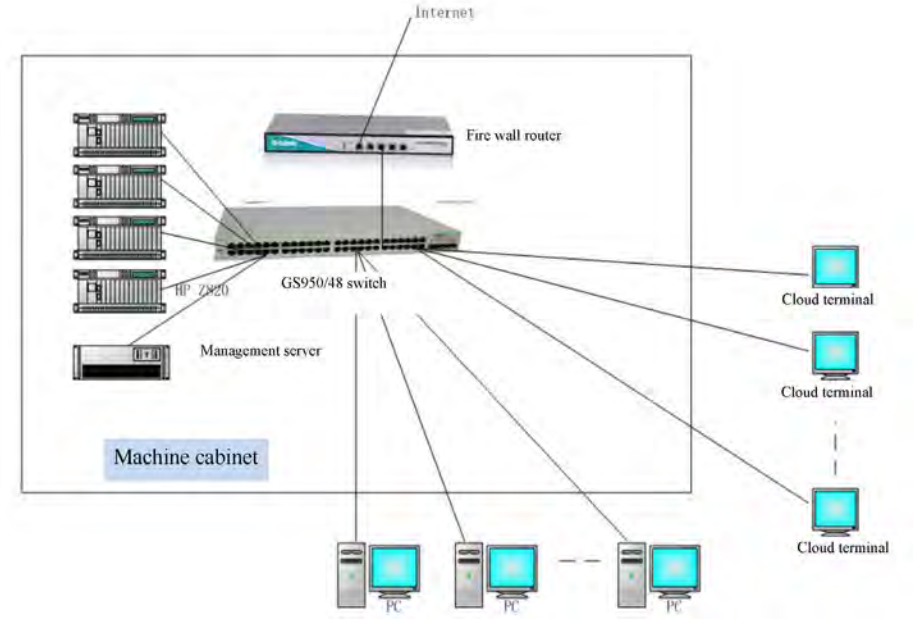

Figure 5.13. (b) Cloud Network System Illustration (Source: Shenzhen xiechuang Tiancheng Technology Co. Ltd.)
图5.13. (b) 云网络系统示意图 (出自: 深圳携创天成科技有限公司)

3. 通过装配化方案策划，优化施工方法，提升工作效率，如: 降低现场焊接作业，推行卡箍式装配方案等

BIM模型的物流管理系统

运用二维码编码系统结合物流管理系统对机电系统的物料和设备等物资的可控管理，增强了物流的及时性和可追溯性。将信息参数录入BIM模型及竣工模型的交付，为后期物业的交接和管理提供便利。

CFD气流组织模拟

运用Fluent软件对塔楼6-9层冷却塔群，L26、50、82层等设备层的风冷机组群和办公区大空间，进行气流组织模拟研究与优化方案设计。包括: ①模拟冷却塔群周围气流组织，获得冷却塔周围气流流场分布、温度场分布与气流流动阻力特性; ②对方案的合

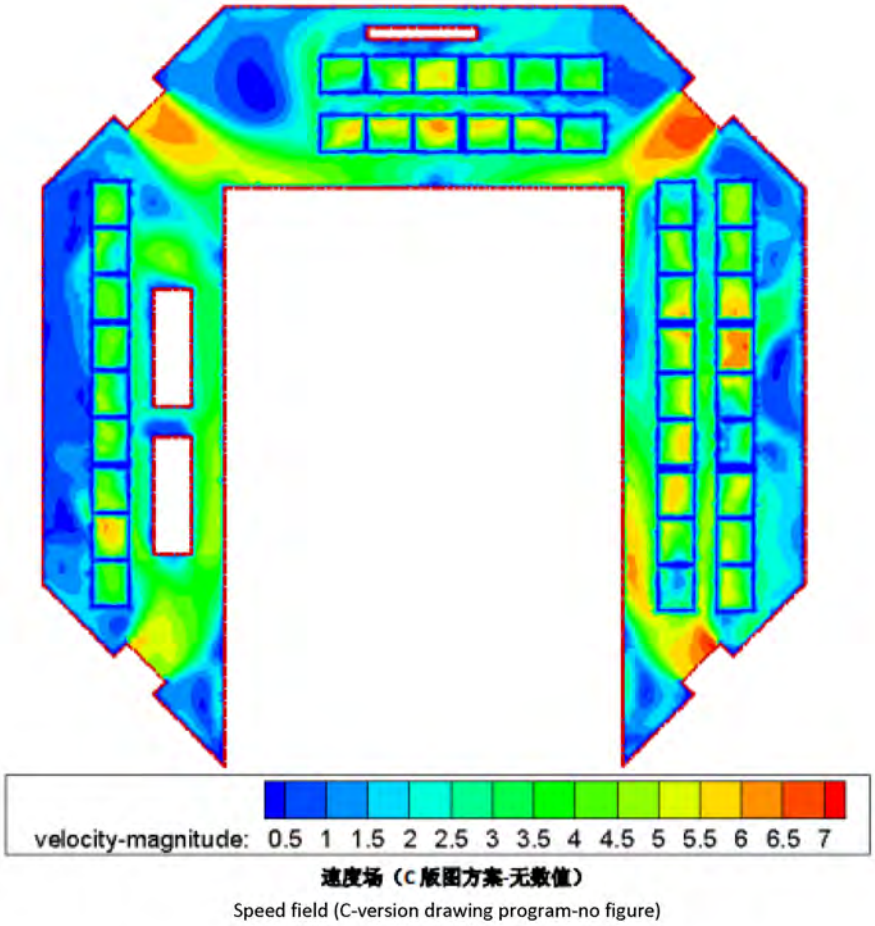

Figure 5.14. (a) Air Flow Organization Simulation (Source: Changsha University of Science & Technology)
图5.14. (a) 气流组织模拟 (出自: 长沙理工大学)

handling measures, and the final preparation of construction drawings.

The engineering construction program and simulation methods as well as the most optimized construction program, are demonstrated as an example.

Preparing System Assembly Drawing Using 3-D Software

Through combining the components' BIM model with digital components using the high precision and automatic coding functions of the software, it was possible to digitalize the precise processing for the pre-manufactured and pre-processed components; ensuring the construction quality of relevant portions. This process enabled 3 factors:

1. The realization of factory pre-manufacturing, logistic shipping, and assembly construction;
2. The ability to compare the pros and cons of pre-manufactured processing construction with the traditional construction approach, thus creating a tool of cost analysis;
3. It increased work efficiency through assembly program planning and optimized the

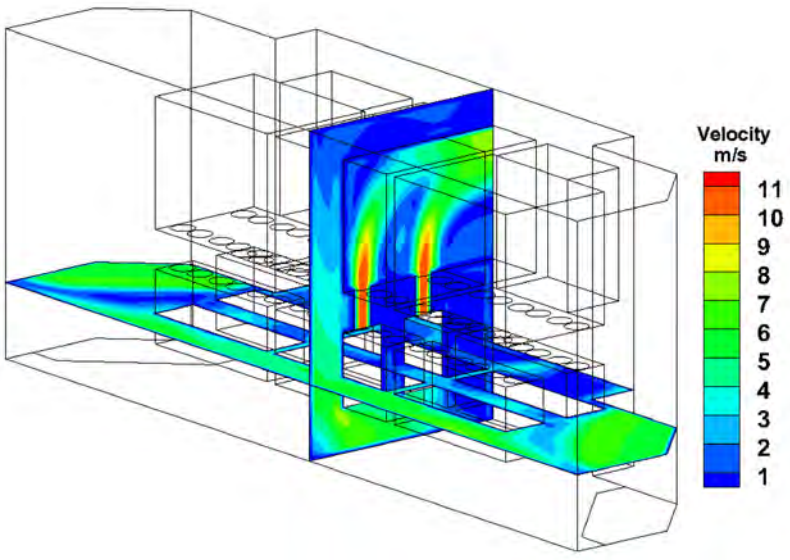

Figure 5.14. (b) Air Flow Organization Simulation (Source: Changsha University of Science & Technology)
图5.14. (b) 气流组织模拟 (出自: 长沙理工大学)

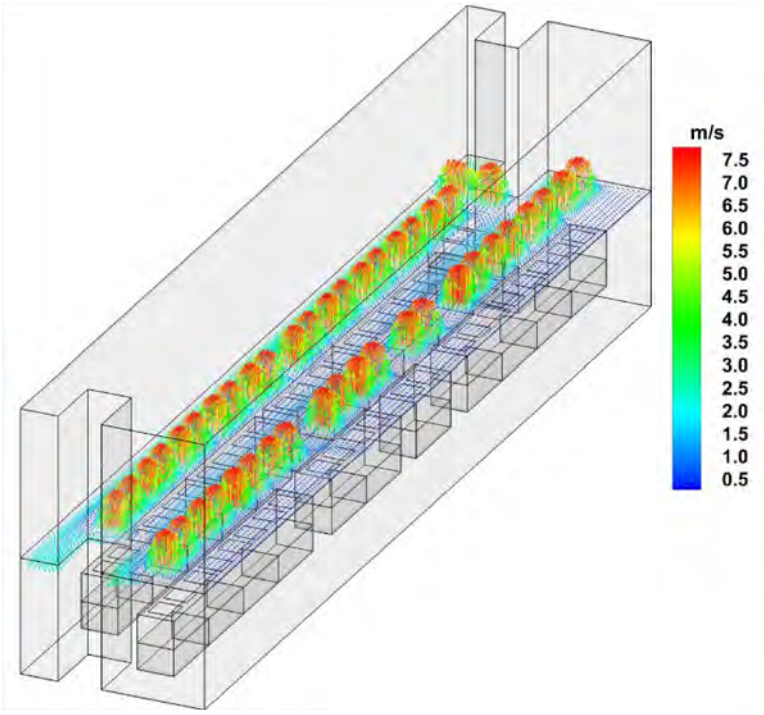

Figure 5.14. (c) Air Flow Organization Simulation (Source: Changsha University of Science & Technology)
图5.14. (c) 气流组织模拟 (出自: 长沙理工大学)

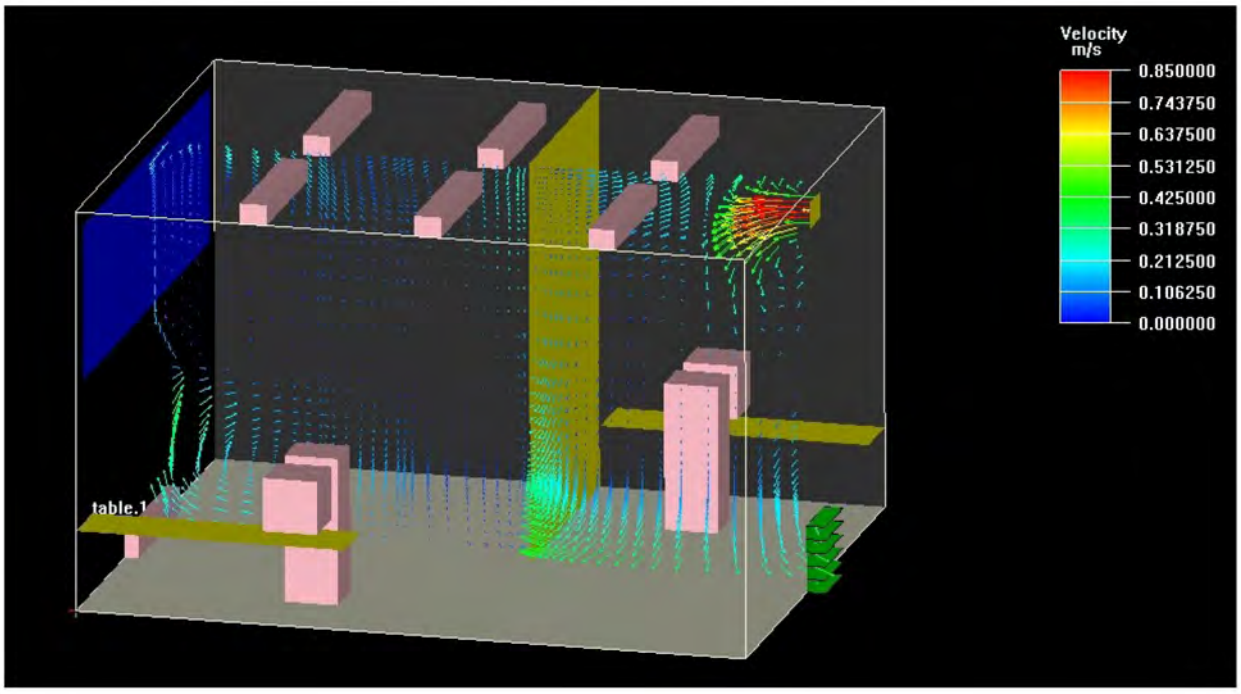

Figure 5.14. (d) Air Flow Organization Simulation (Source: Changsha University of Science & Technology)
图5.14. (d) 气流组织模拟 (出自: 长沙理工大学)

construction approach, such as reducing in-situ welding work and the promotion of a clamping assembly program.

Logistics Management System of BIM Model

The controlled management of the materials and equipment of engineering systems is carried out using a two-dimensional coding system in combination with the logistics management system. This increased the timeliness and traceability of logistics. The parameters are programmed into the BIM model and the completion model facilitated the handover and management of the property at later stages.

CFD Air Stream Organization Simulation

Fluent software is used to carry out air stream organization simulation research and program optimization design for the cooling tower cluster on floors 6-9 of the building. Also, the wind cooling units on equipment levels including L26, L50 and L82 and large office areas were organized in this fashion. This includes: (1) simulation of cooling tower peripheral air stream organization to obtain information on the traits of peripheral air stream field distributions, thermal field distribution and air stream flow resistance; (2) to comprehensively evaluate the feasibility of the program; (3) to improve and optimize the original design program, deciding on the optimal program of cooling tower cluster construction.

Air Flow Organization Simulation

In summary, a highly efficient work flow and powerful execution capacity can be achieved for supertall engineering and general contract project management by setting up unique organizational structures and novel management concepts (see Figure 5.14a, b, c and d). The application of high-tech software and innovative approaches in the design and construction support enables the achievement of precise construction. The establishment of a well-developed management system and closely coordinated work platform are technological breakthroughs in terms of engineering construction competency and more innovations and developments in the field are needed for further technological applications in engineering construction. In-depth application of integrated technologies shall change the pattern of future super high-rise engineering and construction.

理性进行综合评价; ③对原设计方案进行改进与优化，确定冷却塔群施工的最优方案。

气流组织模拟

总之，通过设立独特的项目组织机构和新颖的管理理念，使超高层机电总承包项目管理获得高效率的工作流程和强大的执行力 (见图5.14a、b、c及d) ; 应用高科技的软件与创新手段的集成，辅助于设计和施工，达到精确的施工，建立完善的管理系统以及密切协同的工作平台，是机电工程施工水平的一次科技突破，未来在机电施工方面的科技应用还需要更多的创新和开拓，使科技集成的深度应用改变未来的超高层机电施工的新模式 。