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Author:	Qing Ge, Chief Engineer, Shanghai Tower Construction & Development
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BIM Applications in the Shanghai Tower Construction

BIM在上海中心大厦建设中的应用

Qing Ge

Qing Ge

Shanghai Tower Construction and Development Co., Ltd.
No. 51 West Lujiazui Rd
Shanghai, China, 200120

tel (电话): +86 21 33831187
email (电子邮箱): geqing1971@gmail.com
www.shanghaitower.com.cn

Qing Ge was born in April of 1971. He is a senior engineer with a Bachelor's Degree and is currently pursuing his Master's Degree at the China Europe International Business School (CEIBS). He worked at the Shanghai Xin Jiang Wan Construction Headquarters as a chief engineer, Shanghai Land Holdings Ltd. as a chief engineer, and at the Shanghai Tower Construction and Development Co., Ltd. as a design director. Currently, Qing is a chief engineer at the Shanghai Tower Construction and Development Co., Ltd.

葛清，男，1971年4月出生，高级工程师,大学本科学历，在读中欧工商管理学院硕士研究生。曾任上海城投新江湾城工程建设指挥部总工程师、上海城投置地（集团）限公司总工程师、上海中心大厦建设发展限公司设计总监。现任上海中心大厦建设发展限公司总工程师。

Abstract

The construction of supertall mixed-use projects is a complex and integrated activity which has been a big challenge to construction management due to its wide interdisciplinary collaborations, branch system complexities, and strict quality requirements. Using the Shanghai Tower as a case study, this paper introduces how BIM information technology breaks down traditional barriers among design, construction, and operation to realistically exemplify information sharing and exchange. These are done to solve the problems such as the "information gap" caused by various information exchange based on paper media and the "information island" among application systems while trying to effectively control engineering information collection, processing, storage, and exchange at every construction phrase in order to ultimately optimize technical and economic indicators in the project lifecycle.

Keywords: Skyscraper, Supertall High-Rise, BIM, Project Management

摘要

特大型综合体项目建设是一种复杂、综合的经营活动。其涉及的学科繁多，分支系统复杂，质量要求严格，对建设管理工作提出了巨大挑战。本论文以上海中心项目为案例，介绍了通过BIM信息化技术，打破设计、施工和运营之间的传统隔阂，实现项目各参与方之间的信息交流和共享，以解决项目各参与方基于纸介质方式进行信息交流形成的"信息断层"和应用系统之间"信息孤岛"问题，从而有效的控制项目各个阶段过程当中工程信息的采集、加工、存储、和交流，最终达到项目全生命周期内的技术和经济指标的最优化。

关键词：超高层、BIM、项目管理

BIM Applications in the Shanghai Tower Construction

The construction of supertall mixed-use projects is a complex and integrated activity which has been a big challenge to construction management based on its wide interdisciplinary collaborations, branch system complexities, and strict quality requirements. Architectural information sharing and exchange is one of the main activities in project management. Information technology application and popularization is the key to promoting architectural industrialization.

As an extra-large, multi-functional supertall building, the Shanghai Tower is attempting to achieve not only its building height but also a new level of building concept and management in order to display a leading and exemplary role in the industry. To build a respectable vertical city, a full consideration of market demands and improvements of functioning configurations is required. This also brings great challenges to the construction teams:

Extremely Complex Subsystems

The complexity of building systems are determined by their massive volumes, extraordinary height, various functions, and unique characteristics. Eight different patterns

BIM在上海中心建设过程中的应用

特大型综合体项目建设是一种复杂、综合的经营活动。期间涉及的学科特别繁多，分支系统特别复杂，质量要求特别严格，也对建设管理工作提出了巨大的挑战。建筑工程信息交换与共享是工程管理的主要活动内容之一，信息化技术的应用和普及是推动建筑行业工业化的关键所在。

作为一个特大型、多功能超高层建筑项目，上海中心追求的不仅是建筑高度，更是理念高度和管理高度，在行业中发挥引领和示范作用。必须全面考虑市场需求，完善功能配置，建设一个令人尊重的垂直城市。这也使建设团队面临巨大的挑战：

分支系统非常复杂

巨大的体量、超常的高度、丰富的功能和独特的定位决定了其建筑系统的复杂程度。8大建筑功能综合体；7种结构体系；30余个机电子系统；30余个智能化子系统。这些系统既相互联系，又有一定的独立性；既相辅相成，又常常出现各种矛盾。

项目参建单位众多

建筑系统的复杂性直接决定了项目涉及学科的多样性。目前，仅设计团队就已经包括建筑结构、机电、消防、幕墙等30余个咨询单位。在施工总承包单位管理下，参与施工的包括基础、结构、机械等十几支施工分包队伍。另外巨大的建筑和机电材

of mixed-use complex building systems require seven structural systems, over 30 electrical and mechanical subsystems, and more than 30 intelligent subsystems. These are all correlated but independent from each other to some extent. They also complement each other yet propose conflicts with each other quite frequently.

A Large Quantity of Project Participants

The complexity of building systems directly determines the diversity of disciplines involved in the project. Currently, the design team itself consists of over 30 consulting units in architectural structure, electrical & mechanical engineering, fire protection, and curtain walls. Within the general contractor's management, the construction participants include a dozen of subcontracting teams in foundation, structure, and machinery. In addition, the amount of electrical and mechanical material purchases in large-sized buildings determines the necessity of management for various suppliers through the entire construction process.

A Large Quantity of Innovative Design Concepts and Applications

In pursuit of a goal toward vertical cities and green supertall building construction, the project must apply many advanced design concepts. These concepts include rotation, taper, rising curtain wall system, wind power generation facilities on the tower crown, and public atriums in various areas. Although these technologies are relatively mature on its own, these extensive applications in such tall buildings still lack experience. Engineering design, construction, and management brings great challenges.

Difficulties of the Effective Transmission of Vast Amounts of Information

Diverse disciplines, complex systems, large quantity of construction participants, and each component of the building will be expressed through drawings. It is extremely difficult to preserve, classify, update, and manage such a large number of drawings and mountains of data.

Cost Control Difficulties

The total investment budget of the project is 14.8 billion RMB. Such a huge investment must be protected through accurate calculation models and management approaches especially the combination of the carrying amount of investment to the actual progress of construction in order to grasp the real-time and actual process of the project to ensure the achievement of the ultimate control goals.

All of these challenges in project management require administrators to utilize a series of project management models provided by an effective information technology that can coordinate operations such as design, construction, management, and investment controls through the same platform in order to effectively solve various management problems in the construction process.

BIM, an acronym for Building Information Modeling, is a new three-dimensional digital technology for building information integration. It is one of most powerful tools for supporting project information management. Since BIM can integrate all of the building information such as design, processing, construction, and project management into one unified database, it can create one platform to deliver the building DNA for the full lifecycle management from design and construction to operation coordination.

According to a large number in actual domestic and international project applications along with the McGraw-Hill 2007, 2008, and 2009 reports published for three consecutive years, BIM has been proven to be the futuristic core technology to enhance the architectural industry and real estate technology and management through the practical

料采购量决定整个建设过程中必然要对数量众多的供货方队伍进行管理。

大量创新设计理念和应用

为了追求垂直城市和绿色超高层建筑的建筑目标，本项目上采用了众多先进的设计理念。比如，旋转、收分、上升的幕墙系统，楼顶塔冠部分的风力发电设施，各区域里的公共中庭设计等。尽管这些技术都比较成熟，但是在这么高的建筑上大规模应用的经验还比较缺乏。这也对工程设计、施工、管理提出了不小的挑战。

海量信息有效传递难度大

多样性的学科、复杂的系统、众多的参建单位，建筑物的每一个构件都将以图纸的形式表达出来。大量的图纸和资料堆积如山，保存、分类、更新和管理工作难度巨大。

成本控制难度大

本项目预算总投资148亿元人民币。巨额的投资控制必须用精确的计算模型和管理手段加以保障。尤其必须将账面投资与实际建设进度相结合，才能实时掌握项目过程的实际进程情况，确保最终控制目标的实现。

所有这些工程管理挑战都需要管理者利用一揽子的工程管理模型，用一种行之有效的信息化技术将设计、施工、管理、投资控制等各项工作纳入同一个平台统筹协调，切实解决工程建设过程中的各种管理难题。

BIM 为 Building Information Modeling的缩写，即建筑信息模型，是整合建筑信息的三维数字化新技术，是支持工程信息管理的最强大的工具之一。由于BIM可以将设计、加工、建造、项目管理等所有建筑信息整合在统一的数据库中，所以它可以提供一个平台，保证从设计、施工到运营的协调工作，为建筑的全生命周期管理提供建筑物的DNA。

通过国内外大量的实际项目应用以及麦克劳希尔公司2007、2008、2009连续三年发布的BIM报告显示，BIM在经过二十一世纪第一个十年在全球工程建设行业的实际应用和研究，已经被证明是未来提升建筑业和房地产业技术及管理升级的核心技术（请见图1）。

本项目从2008年底开工之初就全面规划和实施BIM技术。即通过构建数字化信息模型，打破设计、建造、施工和运营之间的传统隔阂，实现项目各参与方之间的信息交流和共享。从根本上解决项目各参与方基于纸介质方式进行信息交流形成的“信息断层”和应用系统之间“信息孤岛”问题；通过BIM所提供的三维可视化沟通加强对成本、进度计划及质量的直观控制；通过构建BIM信息平台，协调整合各种绿色建筑设计、技术和策略。在设计、施工、及运维阶段全方位实施BIM技术，以有效的控制项目各个阶段过程当中工程信息的采集、加工、存储、和交流，从而支持

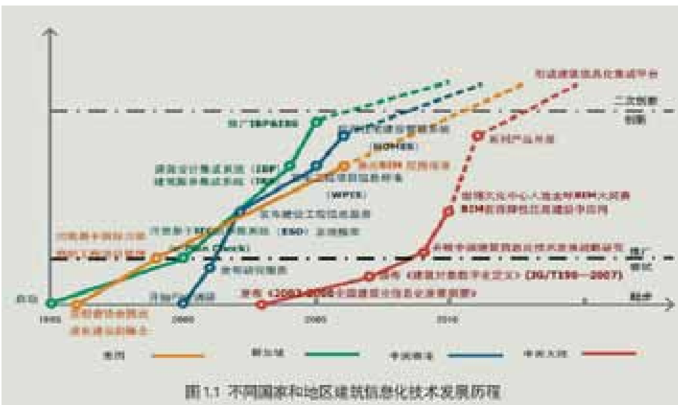

Figure 1. Development of pre-BIM technology of various countries and regions (Source: Research Report on Chinese Building Information Modeling Standard Framework)
图1. 不同国家和地区建筑信息化技术发展历（出自：《中国建筑信息模型标准框架研究报告》）

allocations and research in global construction industry in the first decade of the 21st century (see Figure 1).

The project has planned and implemented BIM technology since it began at the end of 2008. By building digital information models, the project breaks down traditional barriers among design, construction, and operation to realistically illustrate information sharing and exchange. It solves the fundamental problems such as the "information gap" caused by various information exchange based on paper media and the "information island" among application systems. It enhances the visual control over the cost, schedule, and quality through BIM based three-dimensional visual communications. It coordinates all kinds of design, technologies, and strategies in green buildings by building a BIM information platform. A comprehensive implementation of BIM technology during design, construction, operation, and maintenance phases can effectively control engineering information collection, processing, storage, and exchange at every construction phrase in order to ultimately optimize technical and economic indicators in the project lifecycle.

In the project planning stage, there is a working emphasis on BIM project managements and applications of BIM technology. In the BIM project management phase, in order to ensure a full application and effective run, a set of BIM workflow, BIM technology standard, and BIM code is established. To further ensure a full application of BIM in every phase, extra BIM technology requirements are added in the formal bidding contract. In the application of BIM technology, a framework of BIM technology is set in different stages such as design, construction, and operation to meet various requirements in the project through applications of different software technologies. In the overall implementation process of the project, professional collaborative management platform effectively controls all kinds of technical data to achieve the effectiveness, uniqueness, and integrity of the technical data and application; and to achieve data synchronicity in different departments simultaneously (see Figure 2).

Through BIM parametric designs in the design stage, the designers use algorithm variable parameters throughout the entire design process by the setting and judging the rules to modify the proposed design (see Figure 3). BIM and related software plug-ins can analyze and evaluate the building's physical environmental performances such as cooling and heating loads, sunshine effects, energy consumption, and indoor lighting. BIM can quickly and conveniently obtain visual and accurate feedback on the building energy performance. According to analysis results, designers can further adjust and improve the proposed designs to formulate more conductive choices to architectural sustainability and to improve sustainable designs in the overall performance of the building. In addition, different project participants can intuitively understand the designers' intents within the virtual 3D environment to illustrate a unified understanding of the project, to eliminate misunderstanding, and to improve the communication efficiency significantly (see Figure 4). The software can automatically detect the positions and quantity of the conflicting points caused between the components of different professional models. In this case, adjusting and optimizing the design of these conflicting points can not only timely exclude the conflicts caused in the construction process, but it can also significantly diminish the related design changes to greatly improve the comprehensive design capability and work efficiency to decrease the cost growth and schedule delays caused by construction coordinations.

In the construction phase, BIM applications of on-site simulations of construction, deepened designs of construction drawings, 4D construction simulations, and spatial simulation of large-scale

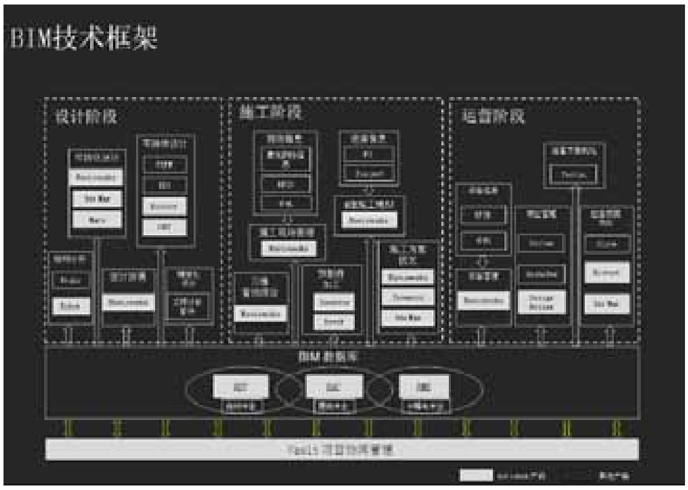

Figure 2. BIM technology framework (Source: Shanghai Tower Construction and Development Co., Ltd.)
图1. BIM技术框架（出自：上海中心大厦建设发展有限公司）

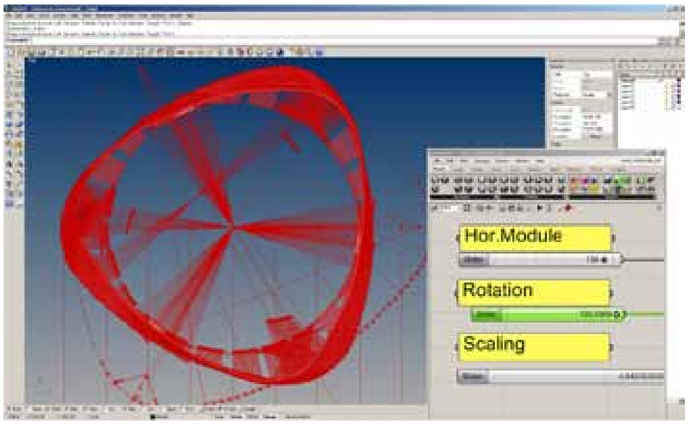

Figure 3. Parametric design (Source: Shanghai Tower Construction and Development Co., Ltd.)
图3. 参数化设计（出自：上海中心大厦建设发展有限公司）

项目的最高决策者对项目进行合理的协调、规划、控制，最终达到项目全生命周期内的技术和经济指标的最优化。

在项目策划阶段，从BIM项目管理、BIM技术应用两个方面着手做了大量准备工作。在BIM项目管理上，为了能将BIM更好的在项目中充分地应用，并真正有效的运转起来，建立了一整套的BIM工作流程、BIM技术标准，以及BIM的制度和相关规范，并通过在正式的招投标合同内增加BIM技术要求环节，来进一步确保BIM能够在各个阶段，各个环节得到充分的应用。另外在BIM技术应用上，针对本项目的特点制定了BIM技术框架，在设计、施工、运营等不同阶段，应用不同的软件技术手段达到项目的不同需求。同时在项目的整体实施过程当中，应用专业的协同管理平台进行项目协同管理，使得各种技术资料得到有效控制，达到技术资料应用的有效性、唯一性和完整性，同时实现各部门数据的同步性（请见图2）。

在设计阶段，通过BIM参数化设计，设计师在整个设计过程中使用算法语言与变量参数，通过对规则的设定与判断来调整设计方案（请见图3）。利用BIM模型及相关软件的扩展功能，对建筑物的冷热负荷、日照效果、能源消耗、室内采光等物理环境性能进行分析与评估，并方便快捷地得到直观、准确的建筑能量性能反馈信息。根据得到的分析结果，对设计方案进行进一步调整与完善，从而做出更加有利于建筑可持续性的选择，实现可持续性设计，进而提高建筑物的整体性能。另外在虚拟的三维环境下，项目各参与方可以直观地了解设计方的设计意图，从而使项目各参与方对项目理解达成统一，消除理解误差，大大提高沟通效率（请见图4）。并且通过软件自动检测出各专业模型构件之间存

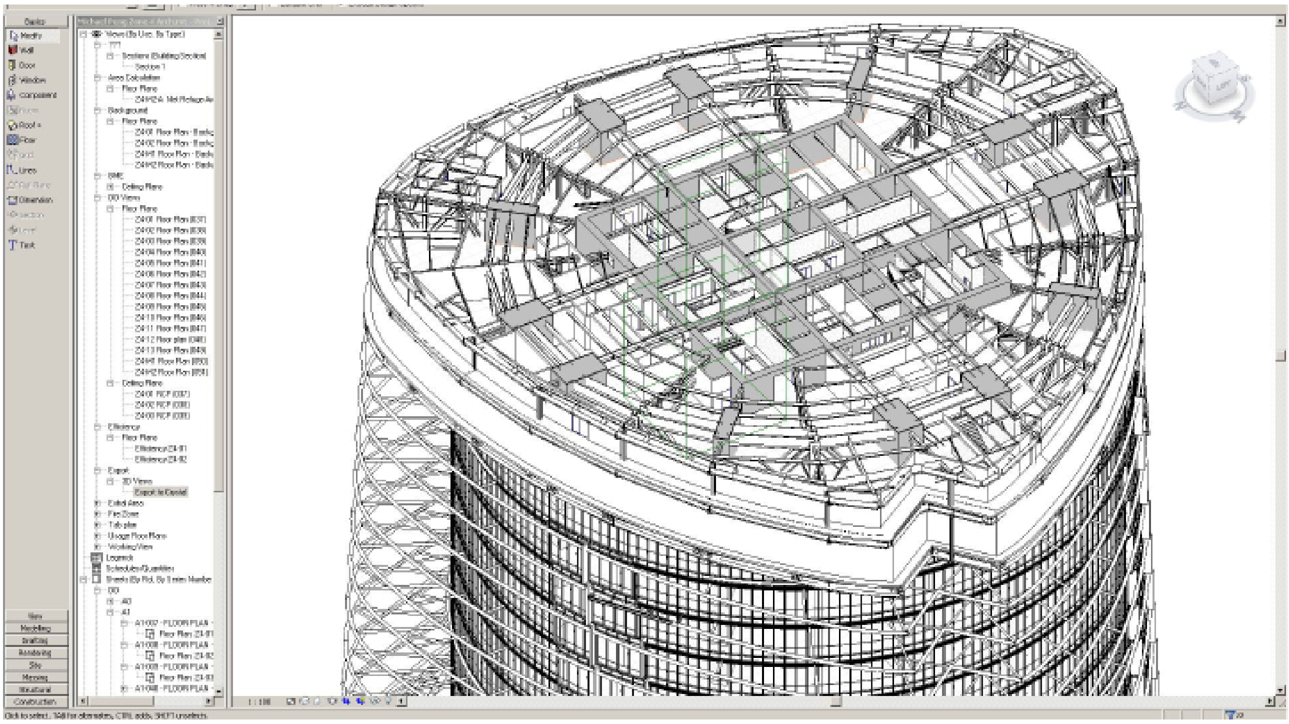

Figure 4. Visualization design (Source: Shanghai Tower Construction and Development Co., Ltd.)
图4. 可视化设计（出自：上海中心大厦建设发展有限公司）

machinery operations can attain an efficient monitoring and management of construction quality, safety, cost, and schedule. For instance, given the limited operating space on the construction site with the comparison between the BIM model and construction site, an available vacant space can be quickly located and its geometric size can be checked to optimally plan and employ the site. At the same time, actual construction can be directly understood through real-time updates of the model (see Figure 5). In addition, BIM models, consistent with the actual situation of the site and construction, combined with the 4D simulations based on the preset schedule of construction can successively illustrate the collaborative working environment which embraces concrete construction, steel structure erection, system operations of steel platforms, and large-scale cranes among many other components so that conflicts can be visually observed among multiple processes. Therefore, appropriately addressing these problems can elude unnecessary financial and time losses caused in practice (see Figure 6).

Currently, in the operation phase, BIM applications have been increasingly administered in research and explorations of data storage and exchange, spatial management, asset management, maintenance

在的碰撞冲突点的方位和数量。这样便可针对这些碰撞点进行设计调整与优化，不仅能及时排除项目施工环节中可以遇到的碰撞冲突，显著减少由此产生的设计变更，大大提高了综合设计能力和工作效率，进而降低了由于施工协调造成的成本增长和工期延误。

施工阶段，通过BIM在施工现场模拟、施工深化图设计、4D施工模拟、大型机械运行空间模拟等方面的应用，实现对施工质量、安全、成本和进度的有效监控和管理。例如针对施工现场作业空间相对紧张的情况，可通过BIM模型比对施工现场，从而快速寻找可以利用的空地，并且查询可利用空地的几何尺寸，方便场地的使用规划；同时也可以直接通过实时更新的模型来了解工程实际的施工情况（请见图5）。另外基于与现场实际情况相一致的BIM模型，结合预设的施工计划进行4D模拟，来依次表现混凝土施工、钢结构吊装、钢平台系统运行和大型塔吊爬升等多工种交叉作业的工况，从中可以直观地看到各工序之间存在的冲突问题。针对这些问题，及时找寻解决方案，从而避免了在实际操作中造成不必要的经济和时间损失（请见图6）。

运营阶段的BIM应用目前已在数据存储与转换、空间管理、资产管理、维护管理、健康监测管理等几个方面逐步展开相应的研究

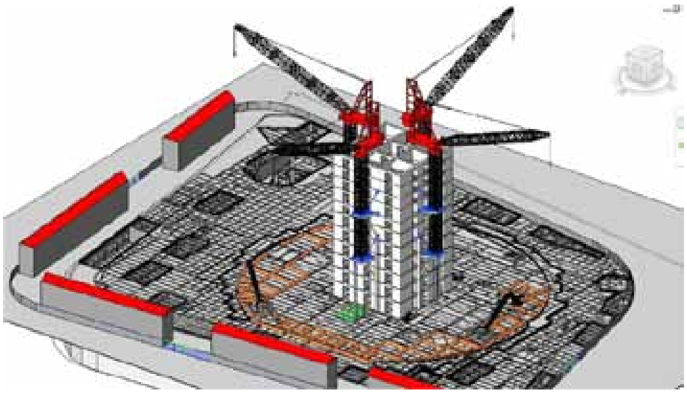

Figure 5. Simulation of the construction site (Source: Shanghai Tower Construction and Development Co., Ltd.)
图5. 施工现场模拟（出自：上海中心大厦建设发展有限公司）

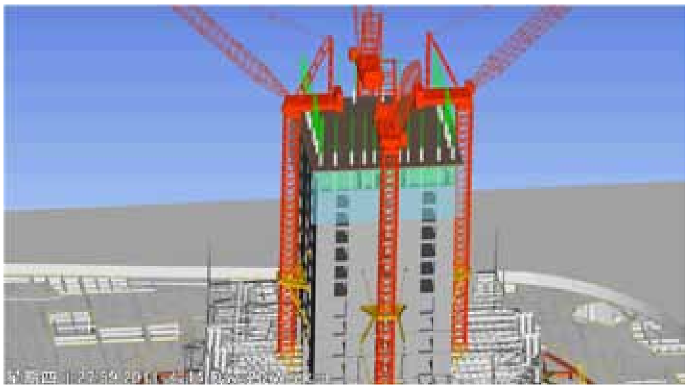

Figure 6. Simulation of the construction site in 4D (Source: Shanghai Tower Construction and Development Co., Ltd.)
图6. 施工4D模拟（出自：上海中心大厦建设发展有限公司）

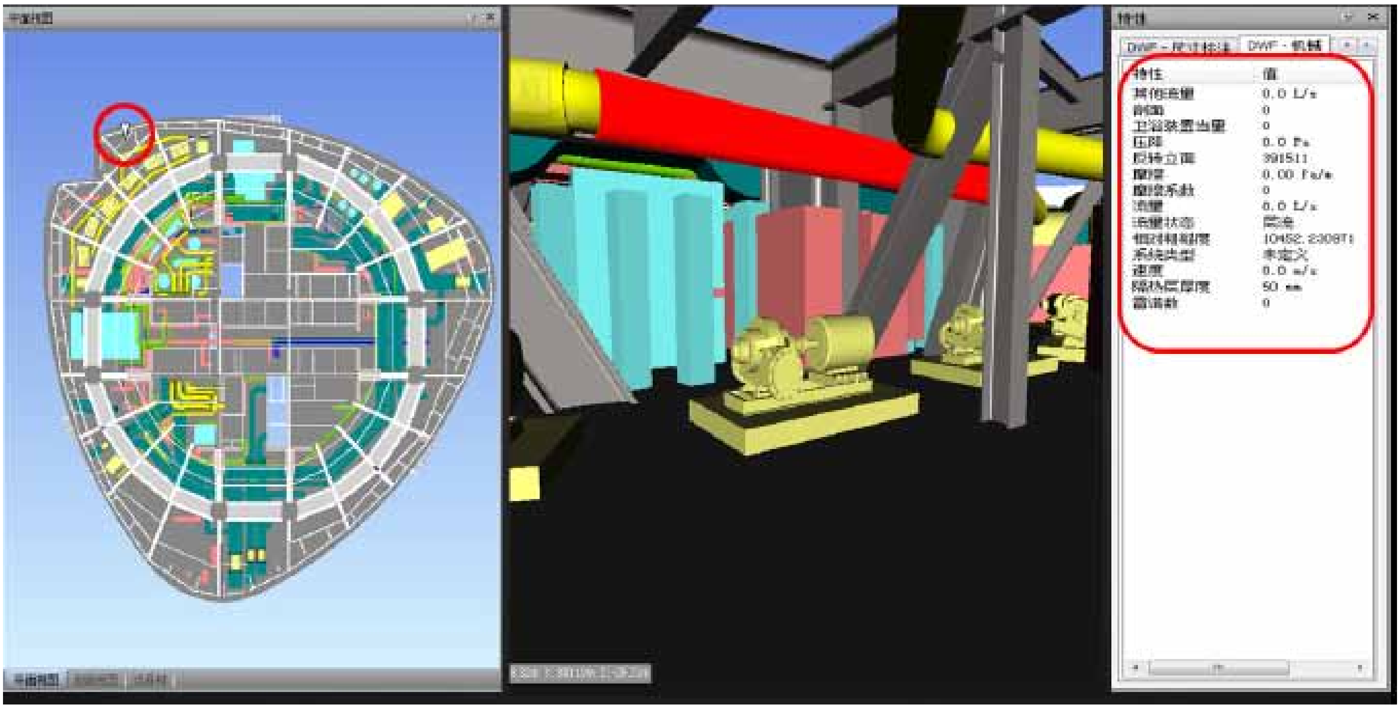

Figure 7. Device spatial orientation (Source: Shanghai Tower Construction and Development Co., Ltd.)
图7. 设备空间定位（出自：上海中心大厦建设发展有限公司）

management, and health monitoring management. Related research results are also progressively tested over time to further improve the management of later operations and maintenances (see Figure 7).

In addition to more advanced and efficient software technologies, the introduction of BIM applications into this project has brought a revolution in work approaches, workflows, and management patterns. Within the in-depth exploration of the BIM applications, a step-by-step transformation will be ultimately recognized starting from Building Information Modeling to Building Information Manufacturing to Building Information Management.

和探索。相关研究成果亦会逐步在项目中得到时间与验证，以进一步提高后期运营维护的管理水平（请见图7）。

BIM在本项目中的引入，带来的不仅仅是更先进、更高效的软件技术，更多的是工作方式、工作流程、以及管理模式的一种变革。随着BIM应用工作的深入展开，最终将逐步实现由Building Information Model（建筑信息模型）向Building Information Manufacturer（建筑信息制造）、到Building Information Management（建筑信息管理）的逐级转变。

References (参考书目)：

McCgaw-Hill (2009). **SmartMarket Report, The Business Value of BIM**

China Exploration & Design Association (2010). **Autodesk BIM implementation plan**, China Building Industry Press.

Tsinghua University (2010). **China Building Information Model Framework Standard.**

Hongkong Housing Authority (2010). **BIM Standard Manual.**