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CONSTRUCTION QUALITY MANAGEMENT – CASE STUDY OF THE SHANGHAI PUDONG INTERNATIONAL AIRPORT TERMINAL II EXPANSION CONSTRUCTION PROJECT

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Abstract
Shanghai Pudong International Airport, which first opened in October 1999, is a major aviation hub in Asia, particularly in the East Asian region, and is the primary international airport serving Shanghai in the People's Republic of China. To cater to the transportation needs of the Beijing 2008 Summer Olympic Games and Shanghai 2010 World Expo, approximately 5 years after it first opened in 1999, the second terminal building started construction. In approximately 36 months, the new terminal building, Terminal II, and ancillary facilities, including new runways and taxiways were completed to a high level of quality and opened in March 2008. This paper presents background information on the project, organizational structures, details of this special project under the influence of the Chinese cultural side and overall government managerial systems; and the quality management techniques used in this mega construction project and the positive consequences. In view of the growing global construction and construction management projects worldwide, the practices in this infrastructure in Pudong Airport provide insights for international companies and construction managers pursuing projects in China.

Keywords
Construction, Quality Management, Airport,

1. Introduction

Shanghai Pudong International Airport is one of the largest airports in East Asia, initially opened in 1999, with Phase II opened in 2008. The airport is the 3rd busiest airport in the world in terms of freight traffic. Prior to the establishment of Pudong International Airport, Hongqiao International Airport was the primary airport of Shanghai. During the 1990s, the expansion of Hongqiao was impossible because the urban area surrounding Hongqiao was developing significantly. As a result, the government had to seek an alternative for Hongqiao International Airport to take all of its international flights. A suitable site was identified in the Pudong economic development zone to the east of Shanghai.

Shanghai Pudong International Airport is located to the east of Shanghai, China about 30 km (19 miles) away from the city center, and about 40 km (25 miles) away from Shanghai Hongqiao International Airport, which occupied a 40 square kilometers (15 square miles) site adjacent to the coastline in the eastern edge of the Pudong district within the boundaries of the Shanghai Municipality. Pudong International Airport (Phase I) was completed in September 1999 and officially opened on October 1, 1999 replacing Shanghai Hongqiao International Airport as Shanghai's international airport and taking over all of its international flights, including regional flights to Hong Kong and Macau. Since it opened to the public, it has become a major aviation hub in Asia, particularly in the East Asian region, and is the primary international airport serving Shanghai in the People's Republic of China.

The first phase of the airport began in October 1997 and took two years to build at a cost of RMB ¥12 billion ($1.67 billion USD). It covers an area of 40 km^2 and is around 30 km from downtown Shanghai. The first phase of the airport included one 4E category runway (4000 m × 60 m) along with two parallel taxiways, an 800,000 m^2 apron, seventy-six aircraft positions, a 50,000 m^2 cargo warehouse, and terminal buildings, airside, landside areas. After that, the second runway was opened in March 2005.

Since it opened, Pudong Airport has never fallen below a 10% growth rate for cargo. During 2002–2003, it had seen near doubling growth of cargo traffic; 87.3% in that period. It has risen from 26th place to 6th place in cargo traffic, with cargo traffic tripling since 2002. During 2003 Pudong International Airport (with Terminal I) had approached capacity of 134,276 aircraft movements, 15,063,600 passengers, and 1,189,400 metric tonnes of cargo and mail. In 2004, the airport handled nearly 500 flights per day, carrying more than 21 million passengers per year in and out of China's most populated city. Forecasts in 2003 indicated rapid market increases from 2004 to 2006 to reach 231,000 aircraft movements, 26,789,000 passengers, and 2,168,000 tonnes of cargo and mail. Pudong Airport had many aircraft movements during peak periods, resulting in most planes having to park on the apron. To alleviate this, and to meet the needs of future growth in passengers and cargo, especially to cater for the needs of the 2008 Beijing Sumer Olympic Games and the 2010 Shanghai World Expo, the construction of Pudong Airport Phase II (Terminal II), included a 2nd terminal, a third runway and a cargo terminal. Phase II started in December 2005 and was fully completed in time for the Beijing 2008 Summer Olympics. Shanghai Airport Authority played a major role in the improvement of facilities.

This paper presents details of quality management during the construction of Pudong Airport Terminal II, including the culture and the managerial system impacts on the construction quality management as well as the methodology used during construction.

2. Brief Project Overview

2.1 Project outlook

Terminal II, located behind Terminal I, opened on March 26, 2008 adding an additional capacity of 42 million passengers a year immediately. It gave Pudong airport a capacity of 60 million passengers and 4.2 million tonnes of cargo annually. A transportation center was established to connect passengers between Terminals I and II before the Shanghai World Expo in 2010. Table 1 presents the scope of the project of Terminal II. The total investment amount was approximately ¥20 billion RMB yuan for the whole expansion project (including the terminal building and the third runway). The terminal building size is 485,500 m^2 (Table 1). Figure 1 provides an outlook of project. Figure 2 presents a three dimension view of Terminal II.

Table 1: Scope Of Project For Pudong International Airport New Terminal II

No.	Type of subprojects	Major subprojects	Quantity or Size
1	Runways/taxiways and apron etc.	The 2nd Runway	3,800m × 60m
		The 3rd runway	3,400m × 60m
		Parallel taxiways to the 2nd runway	3,800m × 25m (2)
		Parallel taxiways to the 3rd runway	3,400m × 25m (2)
		Fast-exit taxiways	3
		By-pass taxiways	6
		Apron berths	42 contact berths, 16 remote berths
		Airfield lighting system	-
		Public security system	-
2	Terminal area	Passenger terminal building (T2)	485,500m^2
		Integrated ground transportation center	-
		Car parking	173,030m^2
		Road system around the new terminal area	56,000m^2
		Common canal of pipeline	-
		Landscaped and greenery areas	-
		Other facilities	-
3	Cargo terminal area	Warehouse of the air cargo terminal	270,000m^2
		Warehouse of air express	19,000m^2
		Office Building	63,000m^2
		Operation site of air cargo	290,800m^2
		Apron for cargo carriers	589,000m^2
		Car parking	20,000m^2
		Other facilities	-
4	Connecting taxiway	Connecting taxiway between the east and west flying areas	1,187m

2.2 Organizational Structure of the Project

Figure 3 presents details of the project's organizational structure. The parties who are involved in the project can be divided into four major groups, Client/Investor, Designers, Contractors, and Construction Managers (Figure 4).

As indicated in Tables 4 and 5, the Owner of the project was Shanghai Airport Construction Headquarters (on behalf of Shanghai Airport (Group) Co., Ltd.) The Architect was Landrum & Brown/Yang Molen (only for the conceptual design scheme by winning the competition), East China Architectural Design & Research Institute Co., Ltd. Project Logistics and Planning was conducted by Shanghai Construction (Group) General Co., Ltd. Project scheduling was conducted by Tongji University (on behalf of the Client - Shanghai Airport Construction Headquarters). Permits were issued by National Development and Reform Commission (for the pre-feasibility study and the feasibility study); The Ministry of Land and Resources (for the land use); Shanghai Municipal City Planning Administration (for the general layout plan); Shanghai Construction Commission (for the construction plan).

The client organization was Shanghai Airport Construction Headquarters. It played an administrative role, which included coordinating the different investors in power supply, gas supply, water supply, drainage, telecommunication, subways and highways, which built the related infrastructure facilities for the project. (All these investors are state-owned corporations and led by different levels of governments).

It also played a business role. For all economical matters, the organization was run as a business company and had to obey the market rules required by China's market economy.

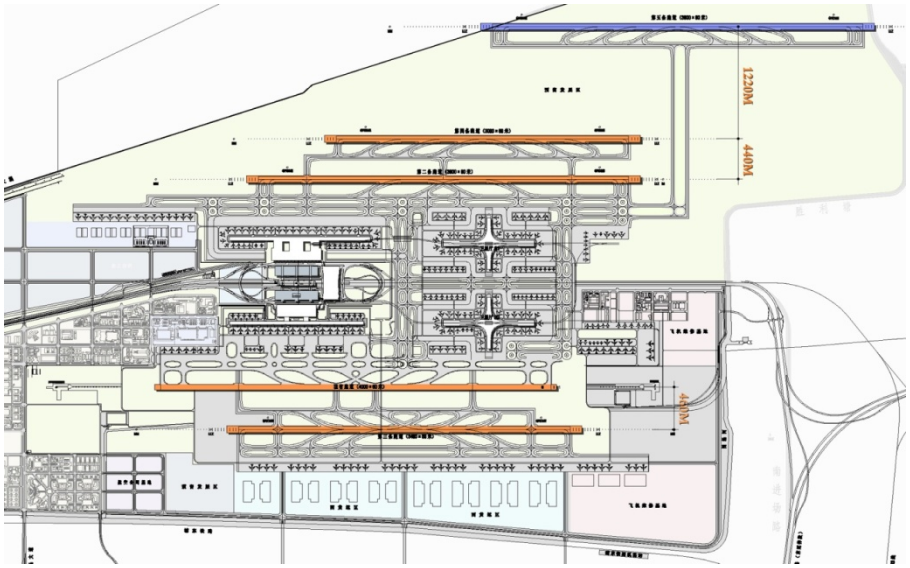

Figure 1: Outlook of the Project

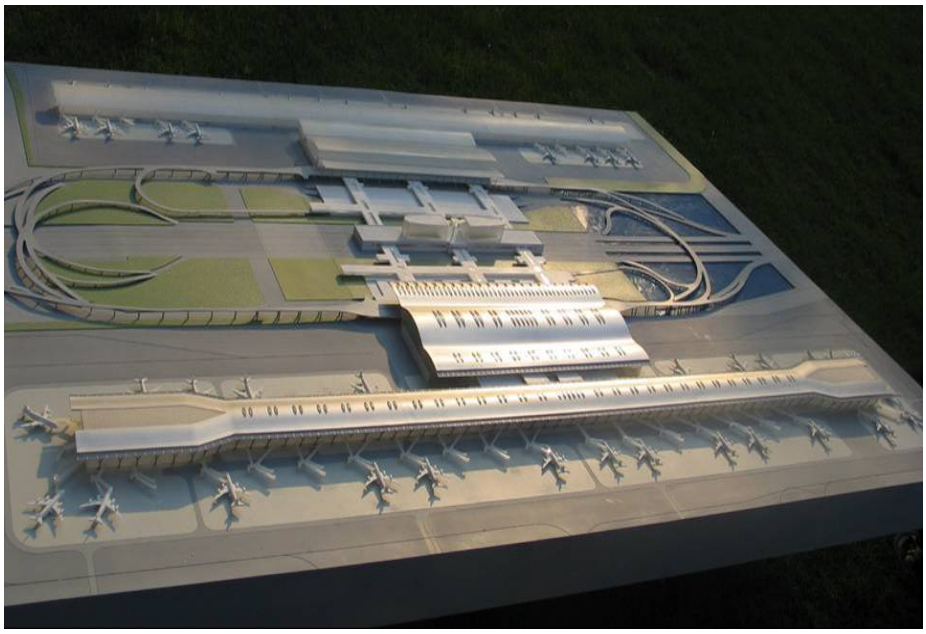

Figure 2: Three Dimension View of Terminal II

However, it should be noted that Shanghai Airport Construction Headquarters is not a legal entity. It is a managerial department under Shanghai Airport (Group) Corporation Ltd., which is the legal entity. Headquarters signed all contracts in the name of the Corporation, which assumed all liabilities and obligations for these contracts. The Shanghai Airport (Group) Corporation Ltd. based Construction Headquarters and the relationships are shown in Figure 5.

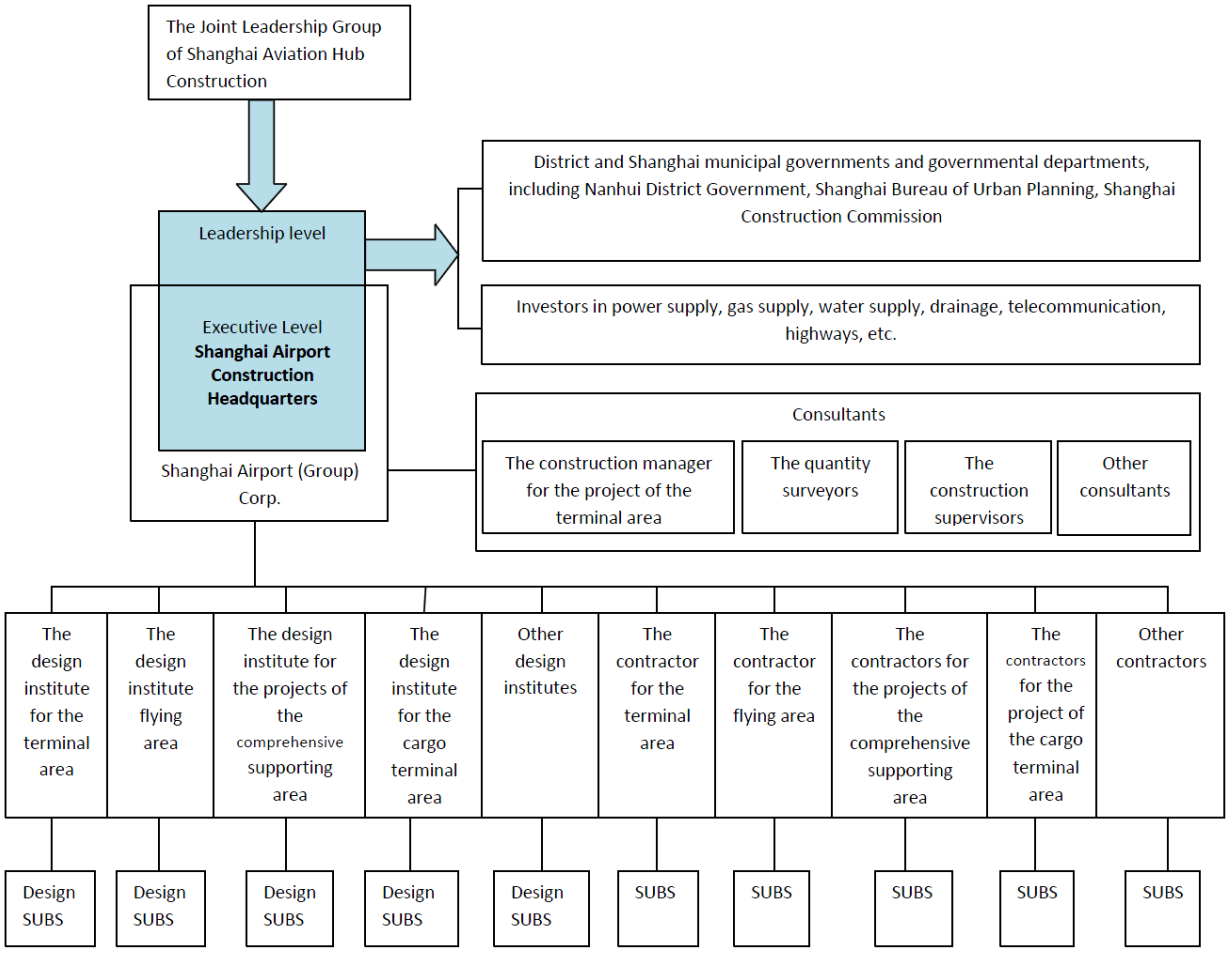

Figure 3: Overview of the Project Organization

The unique characteristics of Pudong Airport Terminal II projects were:

(i) the large-scale public building,
(ii) the complex surrounding environment,
(iii) maintaining normal operation of the existing airport during construction,
(iv) the special steel structural systems,
(v) its tight construction schedule, three years for major construction (from December 2004 to December 2007), and
(vi) its special contracting/delivery method.

The risks and obstacles identified in the project included:

(i) its large size and heavy task, but very short project duration,
(ii) continuing normal operation of the airport during construction,
(iii) installation and commissioning of the baggage handling system (BHS),
(iv) integration of a variety of information systems, and
(v) coordination of the interfaces between different specialties.

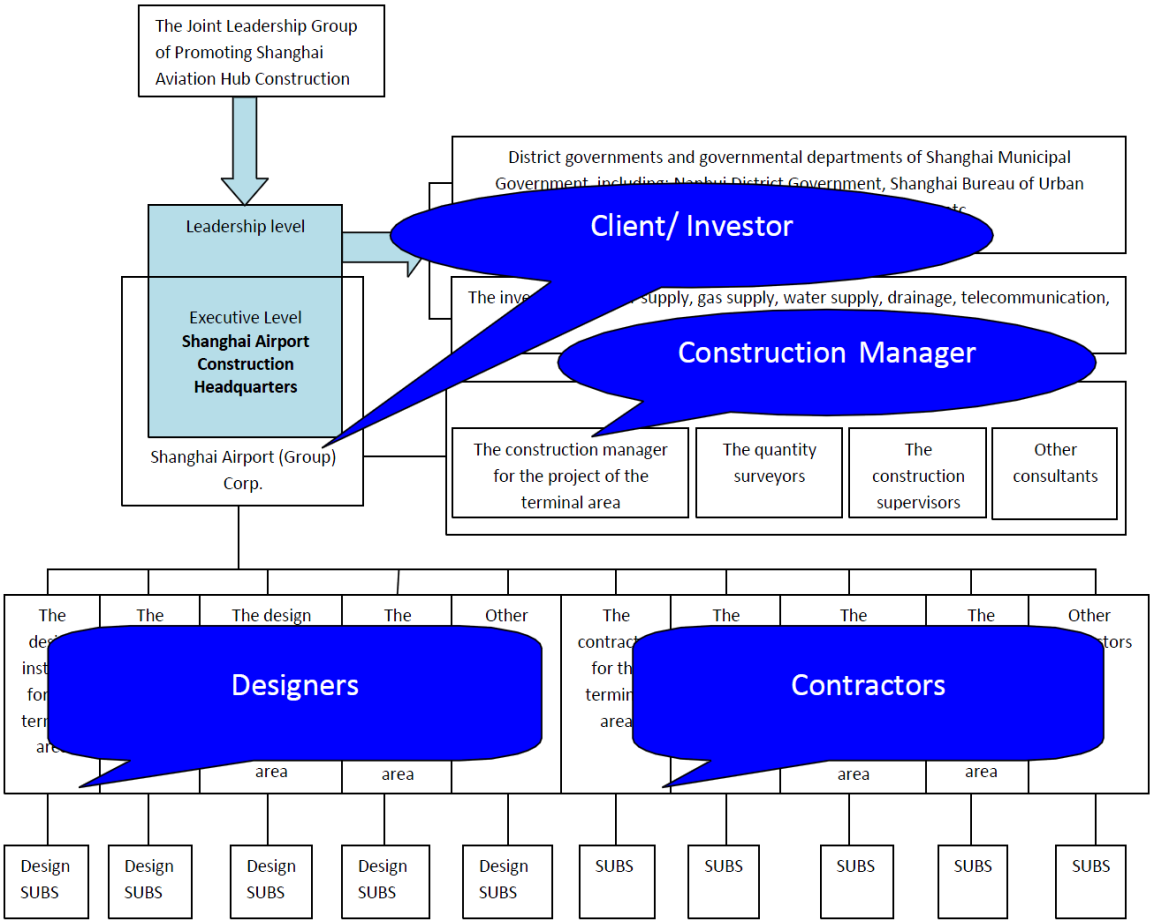

Figure 4: Four Major Parties in the Project Organization

A large number of technologies were used for the construction of Terminal II. Some of the major technologies used included the:

(i) erection of the large-scale steel structure,
(ii) installation of the large-scale metal roof system,
(iii) complex pre-commissioning, commissioning and testing, and
(iv) the integrated system.

These do not include many world-renowned deigns by the architects and engineers, for example, interior finishes such as Bentley Prince Street and Brinton carpets for this new terminal building. Figure 6 shows the ticketing hall of the Terminal II during construction.

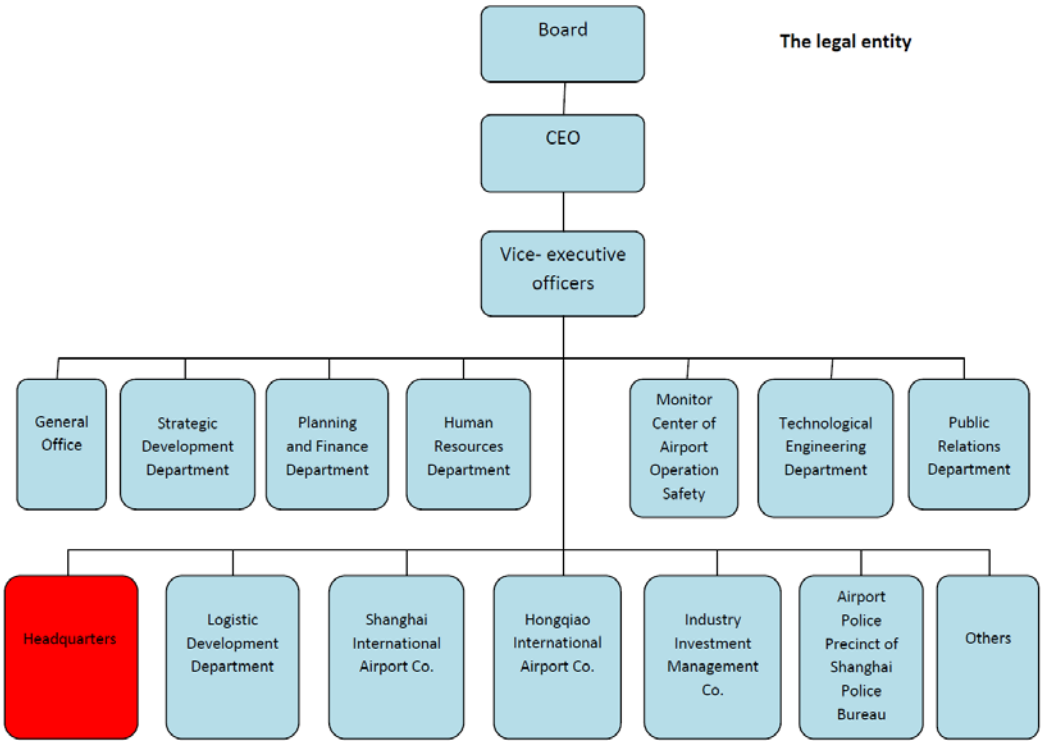

Figure 5: Shanghai Airport (Group) Corporation Ltd. Based Construction Headquarters

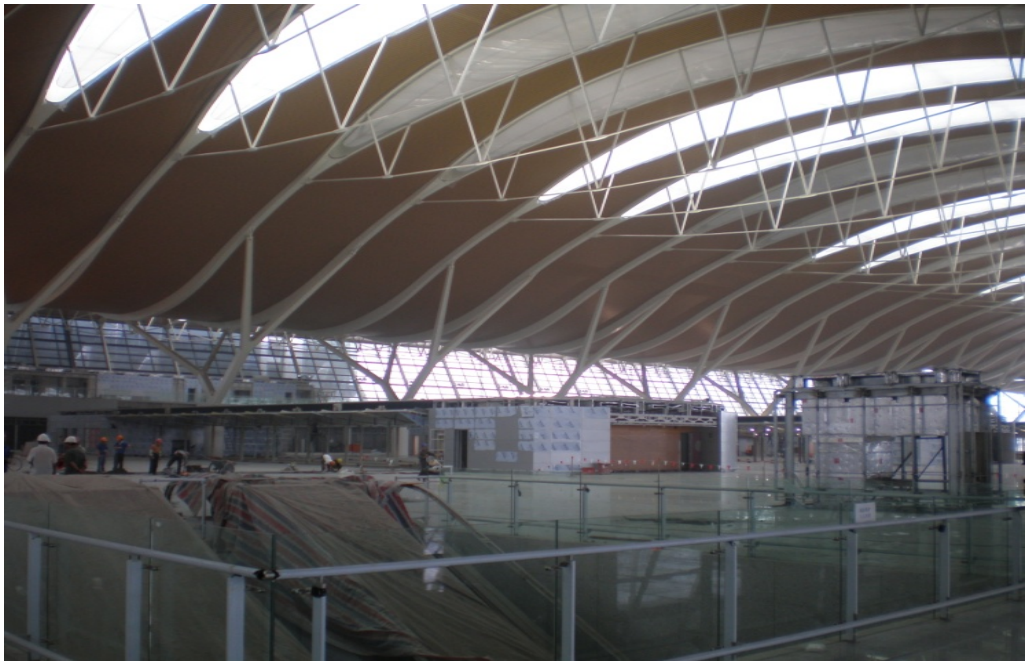

Figure 6: Tickiting Hall during the Constrcution

3. General project scheduling information

The phased construction schedule for Terminal Building II is presented in Table 2.

Table 2: Proposed Phased Construction Schedule for Terminal II

No.	Phases	Proposed construction time
1	Pre-construction	Before December 2004
2	Piling	January – March 2005
3	Foundation pit fencing and excavation	March – June 2005
4	Underground steel and concrete structure	May – August 2005
5	On ground steel and concrete structure	July – December 2005
6	Erection of steel structure	January – August 2006
7	Installation of glass curtain wall	May 2006 – February 2007
8	Installation and commissioning of baggage handling system (BHS)	June 2006 – December 2007
9	Installation and commissioning of the information systems	January – November 2007
10	Substantial completion and final inspection, check and acceptance	December 2007
11	Trial landing/taking off, inspected and permitted by CAAC	January – March 2008

4. The impact of the overall Chinese managerial system and culture on quality management

The challenges, both, risks or opportunities in the construction quality management, came from several aspects of managerial, cultural and human related factors, including the:

(i) fairly new construction supervision system in China,
(ii) governments function or interference in normal construction activities, and the
(iii) cultural and human factor related, mainly the larger number of young workers from the countryside (so called farm workers migrating from rural areas to large cities) with less technical or educational background.

4.1 Construction supervision system

The construction supervision system, which is a quite new system in the country, was put to practice in 1988 in China. It was enforced by the Construction Law of the People's Republic of China. Article 30 of Chapter IV, Supervision of Construction Projects says that the State adopts the system of project construction supervision. The State Council can stipulate the scope of construction projects subject to compulsory supervision (Chinese Construction Law, 2010).

Article 31 states that construction projects subject to supervision shall be supervised by project supervising units with appropriate qualifications entrusted by the project owners. The project owners shall enter into written supervision contracts with the entrusted project supervising units (2).

Article 32 states that the construction supervising units shall, on behalf of project owners, carry out supervision of the construction quality, construction period and the use of construction funds in accordance with laws, administrative regulations and relevant technical standards, design documents and contracts for project contracting. When project supervising personnel think the construction work is not in line with the requirements of project design, technical standards for construction and the terms of the contracts, they have the right to demand corrections from the construction units. When project supervising personnel find that the project design fails to conform to the quality standards for project

construction or the quality requirements as specified in the contracts, they shall report them to the project owners who shall then demand corrections from the design units (2).

Article 33 states that prior to the implementation of the supervision of project construction, the project owners shall inform the construction enterprises in writing of the project supervising unites entrusted, contents for supervision and the scope for supervision (2).

4.2 Different levels of governments played important roles in monitoring projects

Unlike some industrialized countries, in China, governments play an important role in all aspects of the major construction project management. Although indicated clearly in the Construction Law in the supervision of construction projects, different levels of governments also play an important role in 'managing' or 'monitoring' construction quality through construction quality supervision and inspection centers. This brings advantages or disadvantages in different situations.

4.3 Cultural and human factors impacts due to the large number of farm workers migrating to cities

Individual, project team and organizational factors, which influence the behavior of people and the climate at work, can increase or decrease the productivity of a construction project. Human factors, which could cause considerable delays and financial loss relating to a construction project, were reported in the UK construction press (Thevendran, 2004). Since the attitudes and behaviors of every employee affect the company's profitability, it is in the company's best interest to ensure management is skilled at handling these human factors.

Farm workers migrating from the countryside or rural areas in China to major cities in the last couple of decades is a unique phenomenon which appears in the transition from China's planned economy system to the proposed socialist market economy system. Organizations in China have difficulties in hiring trained laborers. However, they must hire the right type of people to manage their most valuable resource, the people. Farm workers are currently the major labor force of the Chinese construction industry. Problems resulted from employing the farm workers included:

(i) the farm workers received little technical, safety training or primary education, and
(ii) instability, caused the high turnover of construction teams.

5. Quality management methods used in the Pudong Terminal II project

5.1 Normalized and standardized plan of quality management

A Normalized and Standardized Plan (NSP) of quality management was used throughout the construction of the Terminal II project. It was adopted as the principle of quality management. The control system of quality management is unique in this project, including:

(i) End-user involvement - End-users include, aviation business department from the Headquarters, operation departments from Shanghai Airport Group Corporation, Airline companies and customs, immigration services, and the related departments,
(ii) Quality first - quality was not higher than schedule, safety, and politics,
(iii) Prevention goes first before any construction activities,
(iv) Study and understanding - Headquarters required all members involved from the contractor to the construction supervisors who had awarded the project to study and understand the bid document and specifications and be familiar with the alternatives shown in the bid document

and the addendums and change orders according to the advices given by the experts who were involved the design, evaluation or preparation of the bid document and specifications,

(v) Three "not allowed" were implemented throughout the construction, which are, the subject work is not allowed to be started if there is no construction supervision outline and detailed regulations made for this work, the subject work is not allowed to be started if there is no construction organization design or specialized construction alternative made for this work, and the work is not allowed to be started in full scale if there is no model work completed or the model work has not passed the check,

(vi) Combining pre-control and procedure management,

(vii) Catching the quality management in key activities,

(viii) Fully utilizing construction supervisors, but not solely relying on them,

(ix) The Headquarters was the planner and organizer of the control system and was at the core of quality management, leading the work of quality management. Within the control system, led by Headquarters and with multi-defenses, the other levels below the first level of quality control, e.g., the construction supervisors, the construction manager, controlled the quality under the unified plan, monitoring and coordination by Headquarters, and

(x) Within Headquarters, the engineering departments were responsible for the construction quality management, monitored the contractors and construction supervisors in the quality, and undertook the work of daily checking and monitoring. The Office of the Chief Engineer was responsible for monitoring and checking the construction quality of the pipe engineering surrounding the site, important and difficult points, and undertook the selective examinations of daily construction quality management.

Figure 7 presents the quality control system of the quality management.

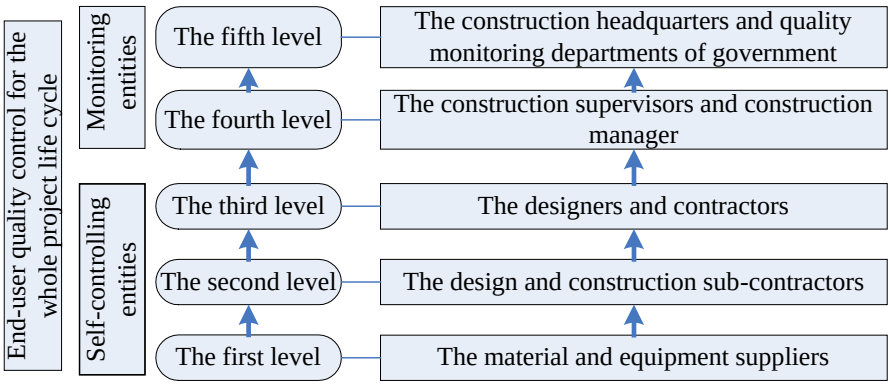

Figure 7: Quality Control System of the Quality Management

5.2 Implementation mechanisms of quality control for the whole life cycle and all aspects

5.2.1 Quality control for the whole life cycle

Quality control for the whole life cycle of the project was implemented. In the preparation stage this involved making construction outline and quality standards for guiding detailed quality standards made during the design and construction stages. The design stage involved making a strict procedure for checking the quality of the design drawings.

In the design stage, strict procedures for checking the quality of the design drawings were implemented. Figure 8 presents that the five 'gateways' used in the quality control process.

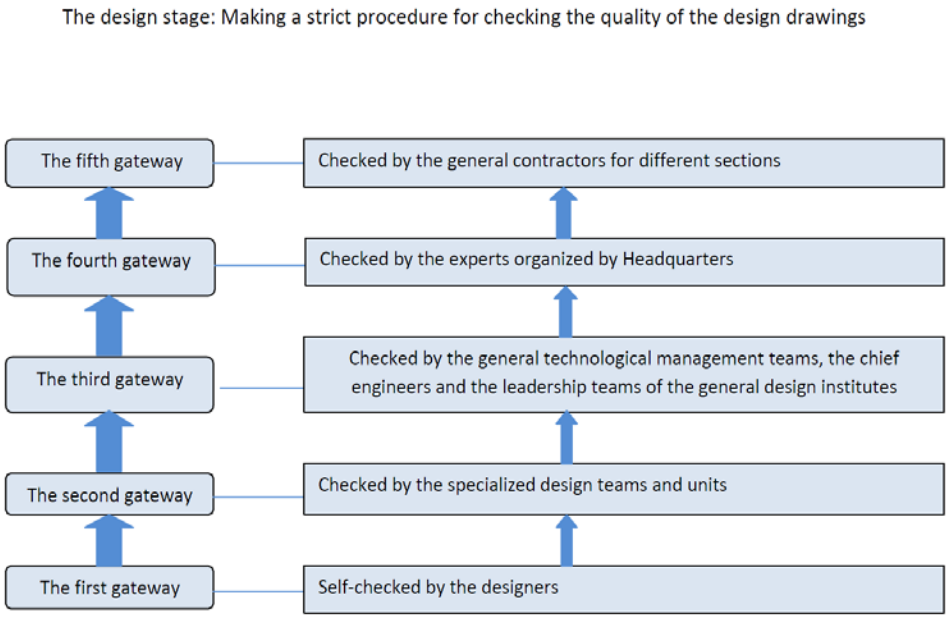

Figure 8: Five 'Gateways' in Quality Control

During the construction stage, the contractors and subcontractors were required to:

(i) establish a complete system of construction quality assurance,
(ii) to make the measurements for construction quality and to carefully conduct "PDCA" cycles,
(iii) to compete the checking system of construction quality,
(iv) to establish the chasing and controlling system of construction quality information, and
(v) to set up a specialized team of on-site construction quality management.

The contractors and subcontractors were regularly organized to check the construction quality for each other and make comments on the quality. Random selective checks were conducted and the contractors were required to make punch lists at each stage and correct them within a limited period of time and with the formal reports in writing submitted to Airport Construction Headquarters.

5.2.2 Quality control for all aspects

Airport Construction Headquarters Main aspects controlled by Airport Construction Headquarters include the:

(i) selection of the contractors with well-known reputation in quality. It is the condition ensuring the construction quality,
(ii) quality of materials and equipment. It is one of the critical factors controlling the construction quality, and
(iii) the selection of the construction alternatives. It is also an important factor affecting the construction quality.

An example for selecting the construction alternative is: selecting from two alternatives for the steel structure of the boarding corridor of Terminal II. Figure 9 presents a random selective check of activity during construction.

Figure 9: Random Selective Check during Construction

5.2.3 Specialized Measures with a Combination of Model Guidance and Technological Innovation
Special measures were used in the construction which included:

(i) model guiding and alternative firstly set up before major construction activities,
(ii) making full use of construction supervisors, but not solely relying on them,
(iii) solving critical technologies by technological innovation, and
(iv) comprehensive examinations and competition.

Figure 10 shows the Baggage Handling facilities under construction.

Figure 10: Baggage Handling Construction

6. Discussion

The construction project was completed in March 26, 2008 and accepted by the inspection committee in terms of quality. According to the design, Terminal II of Shanghai Pudong International Airport's has a passenger-handling capacity of 42 million people per year. According to the master plan, with a total of three terminals, two satellite halls, and five parallel runways, Pudong airport will ultimately have a capacity of 100 million passengers per year. The quality management activities employed in Terminal II construction provided experience for the future construction of Terminal III.

Figure 11: Outside View of Terminal II

The next ambitious expansion includes the addition of the fourth and fifth runways, a Satellite concourse, larger than the size of both of the current terminals combined, and additional cargo terminals that will expand the size of Pudong International Airport. Land reclamation will be included for the fifth runway and some of the cargo terminals. This next expansion will be completed by 2015. It will become one of the world's largest airports by land size.

In the rapid globalised world, construction companies are facing many challenges that were not encountered before. Construction is growing worldwide. Even after the recent major recession in 2009, the predication for the next five years from the top 15 countries in the world indicates that total construction spending will increase from 3.4 to 9.5% (Hanlon, 2009). Infrastructure construction is still performing well even in this time of crisis. This implies that construction professionals in the US, even if they work in their own country, will need international project management knowledge, experience, or awareness to work with their international partners. Pudong Terminal II's experience will also provide a beneficial reference to the international companies pursuing construction projects in China.

7. Conclusion

For a large size construction project, like the Terminal II of Pudong International Airport, the challenges in quality management faced by the project managers are far more than that of a small sized construction project. Although each project has some unique characteristics in its quality management, much experience about the quality management can still be shared and some can be upgraded to common knowledge. Experience from Pudong Airport Expansion Project including the planning, implementation mechanisms and specialized measures could be a contribution to the construction industry.

Pudong Airport Expansion Project is an example of a typical key infrastructure project in China. Such projects are quite different from commercial construction projects conducted in China, for example, it usually has a unique government / owner environment. However, since the investment for such a key project is huge, it usually brings a lot of opportunities for international companies to conduct business. In fact, a large number of international companies had been involved in Pudong Airport Expansion Project. The experiences and organization of Pudong Airport Expansion Project can help project managers outside China to understand this type of project and explore possible future business opportunities for similar projects in China.

8. Acknowledgment

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