A Study of Terminal Three of Beijing Capital International Airport

Course Project

16.781 Airport Systems

Fall 2009

Kai Liao
Contents

1. Background .................................................................................................................. 3
2. Development of Terminal Three Buildings ............................................................. 5
3. Configuration of the passenger buildings ............................................................... 7
   3.1. Terminal 3C ........................................................................................................... 7
   3.1.1. Utilization of the passenger buildings ............................................................. 8
3.2. Terminal 3E ........................................................................................................... 10
3.3. T3D and Flexibility Consideration ............................................................... 11
4. Designs within the Passenger Buildings ............................................................... 12
   4.1. Connections between the Passenger Buildings ............................................... 12
   4.2. Roof and Interior Design ................................................................................... 13
   4.3. Baggage Handling System ............................................................................... 13
5. Ground Transportation and Connection to the City ............................................ 15
   5.1. Subways (Railway) ......................................................................................... 16
   5.2. Highway Solutions ......................................................................................... 17
   5.3. Taxi ................................................................................................................... 17
6. Financing and Revenue Analysis ......................................................................... 18
7. Summary .................................................................................................................. 20
8. References ............................................................................................................... 21
1. Background

Beijing is a single center city, currently with 5 main ‘Ring Roads’ (2nd Ring Road to 6th Ring Road) surround the center connecting different districts of the city. Beijing Capital International Airport is located in the north east of Beijing, between the 5th Ring Road and the 6th Ring Road.

*Location of Beijing Capital International Airport, source: http://www.beijing2008.cn*

Beijing Capital International Airport was initially built in 1959. After several renovations and expansions, until 1999, it has 2 terminal buildings and two parallel 4E runways, 18L/36R, and 18R/36L, which were able to operate independently starting Oct. 27th, 2005. Terminal 1 has an area of 79500 square meters, with a design capacity of 8 million passengers per year; and terminal 2 has an area of 326500, with a design capacity of 27 million passengers per year. Once terminal 2 started to operate in Nov. 1st, 1999, terminal 1 was closed, leaving the total capacity of Beijing Capital International Airport to be 27 Million passengers per year.
In 1999, the traffic in Beijing Capital International Airport was 18.6 Million passengers; and this number grows to 21.6 Million in 2000. Based on this growth rate, it was predicted that the airport would be saturated in 2005. [4]

However, by the end of 2004, the traffic through the airport was already 34.88 Million passengers and 670 thousand tons cargo, forcing the terminal 1 building to be reopened in Sep. 2004. The total capacity was then 35 Million passengers and 780 thousand tons of cargo per year. Even so, the airport was also near saturated.

In addition, in July 2001, Beijing was awarded to host the 2008 summer Olympic Games. It was estimated that the peak traffic around the Olympics would be around 5.6 Million passengers per month. [9] Therefore, a new terminal building and a new runway became necessary.
2. Development of Terminal Three Buildings

The construction of new terminal 3 buildings started on March 28th, 2004, finished on December 25th, 2007, and became fully operated on March 26, 2008. The gross floor area is 986,000 m², with a designed passenger capacity of 43 million per year, and the total investment is $2.82 billion. [4] Compared with similar terminal developments in other regions, the speed of construction is satisfying, and the cost is reasonable.

<table>
<thead>
<tr>
<th>Airport</th>
<th>Size (sq m)</th>
<th>Cost ($ billion)</th>
<th>Construction period</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beijing Capital International Airport, Terminal 3</td>
<td>986,000, one runway</td>
<td>3.82</td>
<td>3 years, 9 months</td>
</tr>
<tr>
<td>London Heathrow Airport, Terminal 5</td>
<td>300,000, one taxiway</td>
<td>8.76</td>
<td>7 years</td>
</tr>
<tr>
<td>Hong Kong International Airport</td>
<td>550,000, two runways</td>
<td>5.56</td>
<td>5 years, 5 months</td>
</tr>
<tr>
<td>Incheon International Airport, Seoul</td>
<td>496,000, two runways</td>
<td>6.54</td>
<td>6 years</td>
</tr>
</tbody>
</table>

*Source: National Development and Reform Commission*

From the designing stage, it was known that the new terminal 3 buildings would be restricted to the area between the East Runway (18L/36R) and the new third runway, which is parallel and to the east of the original East Runway (18L/36R). The distance between the East runway and the new runway is 1525m. [6]
The core parts of the new terminal 3 include two ‘Y’ shape passenger buildings, which are named T3C and T3E. (The names of T3A and T3B are not used to prevent the confusion with the original 2 terminal buildings.) A finger shape passenger building T3D between T3C and T3E, and a Ground Transportation Center (GTC) connected to T3C.

The ‘Y’ shape terminal building has been used previously by the designer, Norman Foster, in Hong Kong Chek Lap Kok Airport (HKG). In Chek Lap Kok Airport, a single ‘Y’ shaped passenger building is used.
However, the design capacity of the Terminal 3 building of Beijing Capital International is much larger than that of the HKG. If a single building were used in Beijing, the distance from the north end to the south end of the building would be 3 km. If an airplane parked on one side of the building and would have to take off through the runway at the other side of the building, the taxi distance could reach 4 km. As a result, the designer decided to build independent buildings for terminal 3 of Beijing Capital International Airport.

3. Configuration of the passenger buildings

In the current design, T3C is a finger tier type of passenger building; T3E can be viewed as a midfield concourse; and T3D can be seen as a natural extension of T3C.

3.1. Terminal 3C

Terminal 3C (T3C) is a typical finger pier design of passenger building. It can accommodate a larger number of gates in the limited space. However, the walking distance, especially for transfer passengers, can be long in this kind of design.

In this case, the designer has tried to alleviate the problem by shorter the length of the fingers, and setting the elevators connecting the departure floor (floor 3) and the arrival floor (floor 2) in the middle of the ‘Y’ shaped building. The lengths of the fingers are reasonable, with a longest distance from north to south of 970m, a longest distance from west to east of 790 meters. [2] Given its geometric configuration, the average walking distance for domestic O-D passengers is reasonable. However, for domestic transfer passengers, since they have to first walk to the center of the building, go up one floor, and then go to the departure gate, the walking distance could be more than 1.5km. Moving walkways and better coordination of the connecting flights are necessary to solve the issue.
3.1.1. Utilization of the passenger buildings

Building T3C is used for international and domestic passenger check-in, domestic departure and arrival. Buildings T3D and T3E are used for international departure and arrival.

T3C has 5 floors above ground and 2 floors underground. The first floor is the ramp; the second floor is used for domestic arrival, baggage claim, and transferring to T3D and T3E through an automated people mover (APM); the third floor is used for domestic departure; the fourth floor is used for international and domestic check-in, and the fifth floor is used for commercial usage.

Both international and domestic departure passengers get access to the airport through the fourth floor of T3C. A total number of eleven check-in stations, with 292 counters altogether, lie parallel from east to west, assigned to different airlines. Passengers taking different airlines will get access to the check-in area through six different gates.
The advantage of such a design is that all the departure passengers can check in once they arrive at the airport. Thereafter, the moving speed will increase and the required space will be reduced.

However, since all the departure passengers will use a single check-in area, the space can be crowded during peak hours. There is also little extra space available for future check-in facility expansion. In addition, since the international departure is in another separated building, the baggage processing procedure can be challenging. Together with the effect from the large number of traffic go through this terminal, the required latest check-in time for domestic departure is about 45 minutes before scheduled departure time, and about 60 minutes for international departure. [6] This time requirement can have obvious effects on the total travelling time of a passenger, especially for passengers taking domestic short haul flights.

The third floor is designed for domestic departure. Such a design would allow the passengers to go straight after check-in and decent for only one floor before reaching the
waiting area. Some commercial regions have been arranged on the third floor, mainly near the center of the ‘Y’ shaped region. Such a design will allow the shops and restaurants have more exposure to the departure passengers, who are more likely to spend some time in shopping and dining than arrival passengers.

The second floor of T3C is used for domestic arrivals. Such arrangement can avoid the meeting of domestic departure passengers and arrival passengers. In addition, for transfer passengers, either domestic-domestic or domestic-international, the transferring procedures can be processed on the second floor of T3C.

The fifth floor of T3C has been arranged for commercial facilities. Such arrangement is flawed in that after checking in from the 4th floor, most passengers would descend to 2nd or 3rd floor to wait for their flights to transfer to another building. Unless they arrive at the airport too early or they have known in advance that there are specific stores or restaurants they want to visit, the passengers will not have the opportunity to pass by these commercial facilities.

3.2. Terminal 3E

Terminal 3E, source: www.airlinks.net
T3E is a ‘Y’ shaped midfield concourse. The first floor is the ramp; the second floor is for international departure, the custom and APM station; and the third floor is for international arrival.

The facility arrangement of T3E is similar to that of the T3C. But its departure and arrival arrangement is reversed of T3C. Such arrangement has given priorities to the international departure passengers, and shortened their walking distance. Departure passengers will use APM to travel from T3C to the second floor of T3E. Such arrangement will avoid changing floor for the departure passengers.

However, for arrival passengers using T3E, there are only 10 immigration service points for both foreign and Chinese passengers [6]. There is no obvious expansion ability for the service points. Since the 2 runways besides terminal 3 are operating independently, if two airplanes arrive at the same time, the immigration service point could be a bottle neck.

### 3.3. T3D and Flexibility Consideration

T3D is an extended finger of T3C, with a gross floor area of 91,000 square meter, 385 meters long from south to north, and 108 meters wide from east to west. It is now used for international departure and arrival with a similar arrangement with that of the T3E.

In the initial designing stage, it is predicted that the traffic through Beijing Capital International Airport would reach 63 Million in 2015. Under this assumption, the first stage construction would only include T3C and T3E. The space between the two passenger buildings is reserved for future expansion when necessary.

However, the growth of traffic in Beijing has beyond expectation. In 2004, the traffic was 34.5 Million, in 2005, the number jumped to 41 Million and in 2006, the number is 48.7 Million. Following this trend, under a liner growth assumption, with a moderate to low annual growth rate of 6 Million passengers per year, the traffic would reach 60 Million passengers in 2008. Seeing such a trend, the reserved area was put into use. The terminal
3D construction started in March 2006. Thereafter, the capacity for the Beijing Capital International Airport after T3 expansion can reach 82 million.

Traffic growth trend observed in 2006, date source: www.bcia.com.cn

In fact, although prediction is hardly accurate, the growth trend slowed down by the economic downturn in 2007 and 2008, leading to a traffic of 55.7 million passengers in 2008, the traffic jumped significantly in 2009. In the first 11 month of 2009, traffic through Beijing Capital International Airport has already reached 60 million, and is going to reach 65 million by the end of the year.

Although the flexibility consideration in the original design of terminal 3 has solved the immediate problem of unpredicted traffic growth, the airport has left little space for future expansion. Therefore, a second airport for Beijing is going to be constructed starting 2010 and is going to be finished in 2015.

4. Designs within the Passenger Buildings

4.1. Connections between the Passenger Buildings
Due to high capacity requirement and the space constrains from the two parallel runways, the new terminal 3 buildings has a length of 2940 meters from the south end to the north
end. Because the utilization of the passenger buildings have been separated based on international and domestic passenger usage, international departures and arrivals have to travel between T3C and T3E, with a distance of around 2 km.

In order to reduce the passenger transportation time between the passenger buildings, an automated people mover (ATM) system is used. The total length of the ATM in each direction is 2080 meters, making three stops at T3C, T3D and T3E respectively. The total travelling time is 4 minutes for the whole trip. The interval between two consecutive ATMs is 3 minutes, and is able to transport a maximum of 4227 passengers per hour each direction.

4.2. Roof and Interior Design
The terminal 3 buildings have a total number of 155 windows on the roof, which are all facing towards southeast. This design can take advantage of the day light coming from southeast in the morning, and avoid western exposure in the afternoon. In addition, glass walls are utilized across the terminal buildings. Such a design can allow natural light come into the building, reducing the requirement for lighting system. The glass walls are 15 degree inclining towards outside of the building. Such a design mainly considered to avoid the reflection from the glass and give a better view of the airport to the passengers. [Foster] In addition, the extra roof space can shorten the time that the sunlight comes directly into the buildings.

Also, parallel lines going south-north wise are designed on the ceiling. This will assist passenger in identify directions. It is help full particularly in this kind of symmetric buildings. However, to fully take advantage of the ceiling line design, passengers have to be familiar with the shape or general layout of the passenger building first. This is something not many passengers would do in advance. Particular signs are necessary to educate the passengers.

4.3. Baggage Handling System
Since all departure passengers will check-in their baggage once they enter T3C, and all arrival passengers will pick up their baggage in T3c as well, the baggage handling
process is challenging. Especially for international arrival and departure passengers, whose baggage has to be transferred between the two buildings.

As a result, an advanced baggage handling system with a total length of 68 km is installed in terminal 3 buildings. The system is able to process a maximum of 19200 pieces baggage per hour. It can travel at a speed of 7 meters/second, which allow the baggage to be transferred from T3C to T3E in 4.5 minutes. [7] Considering the travel time of the passengers through APM is about 4 minutes, and under a Poisson arrival process, given the APM arrival interval is 3 minutes, the average waiting time for APM is about 1.5 minutes. Therefore, the speed of the baggage handling system allows the baggage to arrive at the baggage claim area almost the same time with the international arrival passengers. It also allows the baggage transfer time between flights to be as low as 25 minutes. [6]

RFID is also used in the system to keep track of each baggage. Each baggage is assigned to a single baggage holding plate, which will be able to scan the bar code on the baggage from 6 different directions. This helped to reduce the baggage mishandling rate to 2.3 per 1000 piece in the T3 terminal building. [6] However, it should be noticed that 49% of
baggage mishandling happened during flight transferring process in 2008 [from SITA]; and only about 10% of the total passenger using T3 are connecting passengers. As the airport grows to be a connecting hub, this low mishandling rate will be challenged.

However, the baggage handling system also brought some issues. First, the investment on the system is $240 million. It also requires a longer learning process for the maintenance engineers to become familiar to the system. During the pre-Olympic test period between May and August of 2008, the system broke down for three times. The once took place on June 12th is caused by mechanical problem, causing 4.5 hours to recover (from 6:30am to 11:00am), leading to 80% of the baggage mishandled. [7]

5. Ground Transportation and Connection to the City
A ground transportation center is connected to T3C from the south. It has 4 floors. The two floors below ground are used for parking area, with a total number of 7000 parking lots. The first floor above ground is used as terminals for airport shuttles and inter-city buses; and the second floor is used for railway system.

[Image of Ground Transportation Center, Source: http://www.caacnews.com.cn]
5.1. Subways (Railway)

The subway operates underground when it is in the city center (3rd ring road), and will emerge from the ground between the 3rd ring road and the 4th ring road. It will keep operating above ground until the airport.

Subway is a reasonable solution for ground transportation connecting the Beijing Capital International Airport and the city center.

First of all, the size of the airport can guarantee enough passengers to cover the cost at a reasonable operation frequency, so that people don’t have to wait long for the trains. At the initial stage, the subway is operating at 15 minutes interval. It will be operating at a 4 minutes interval in the future, with a capacity of 4500 passengers per hour each way during peak hours. [4]

Second, the subway and other public transportation system are convenient in the city. Major business districts, tourist attractions, schools and major residential districts can be reached with public transportation system. The train stations of Beijing are also connected with the subway.

Also, subway is the fastest method to reach the city center from the terminal 3 building. The distance from the airport Dongzhimen (on the east 2nd ring road of Beijing, center city) is 26 km, and it only takes 16-18 minutes to travel from the Airport to Dongzhimen by subway. Due to traffic conditions within the city, it usually takes a much longer time to travel to the city by rubber-tired vehicles.

Although the travelling time of subway is very short, it mainly suits passengers without much baggage. Even if the space on the ‘Airport Line’ subway is sufficient, it won’t be the case for the public transportations within the city.

In addition, the ticket price for each passenger using the ‘Airport Line’ is about $3.50. Compared with a taxi cost of around $9 to the same location from the airport, the cost for the subway is not very competitive.
5.2. Highway Solutions

The rubber-tired mode is the major transportation method connecting the airport and the city center. This mode is cost effective. But traffic jam is an important issue during peak hours, especially for the part within the city.

Accompanying the construction of the third terminal building, three highways are also built. Six airport shuttle lines are also provided and can connect major districts in the city to the airport. The ticket price each way is less than $2.50 for all the six lines connecting the airport and the center of Beijing, with an departure interval of 15 minutes or 30 minutes.

The frequency and price arrangement is attractive to passengers sensitive to traveling cost but not particular sensitive to time displacement.

High quality of airport shuttle service can reduce the total number of vehicle visit the airport. As a result, the traffic jam on the highways can be alleviated, and the emission caused by private cars will be reduced.

5.3. Taxi

It is found that the process of taking taxi has been problematic for arrival passengers through terminal 3 of Beijing Capital International Airport.

First of all, the baggage claim area for both international and domestic flights is on the second floor of T3C, but the taxi waiting area is on the first under ground floor. There are only 6 elevators in this area connecting the two floors. The arrival passengers with baggage have to use the elevator. During the peak hours in the afternoon around 4-5 pm and at night around 8pm, the elevators are running at full capacity. Waiting lines are accumulating in this area.

Second, under the utilization design of the airport, all arrival passengers will be accumulated first and then take the ground transportation to the city. There were only 2
taxi stands in the initial arrangement; the taxi waiting time can be above an hour. Although, the number of taxi stands has been increased to four, the problem of long taxi waiting time still exists. [6]

The issue is not that there are not enough taxis. In fact, both taxis and passengers are waiting in long queues for each other. The ‘interface’ has become the major issue. Considering the span of the T3 building from east to west is more than 790 meters, additional taxi stands should be able to be arranged. In addition, once the 6 elevators become the limiting factor, considering other locations for taxi stands is also necessary.

6. Financing and Revenue Analysis

The operation of the new terminal 3 building has led to a dramatic change in the revenue and cost structure of Beijing Capital International Airport.

The total revenue of BCIA has increased for 31.5% from ¥3.516 Billion RMB to ¥4.624 Billion RMB. Among which the aeronautical revenue has increased by 13.0% from ¥2.490 Billion RMB to ¥2.813 Billion RMB; and the non-aeronautical revenue has increased by 76.5% from 1.026 Billion RMB to ¥1.811 Billion RMB. Also it should be noticed that in addition to the fact that the growth rate of non-aeronautical revenue exceeded that of the aeronautical revenue, the weight of non-aeronautical revenue in the total revenue is also growing rapidly. The non-aeronautical revenue is only 29.2% of the total revenue in 2007, but the figure increased to 39.2% in 2008.
The construction and operation of the new terminal building has also increased the cost of the airport significantly.


The total cost of BCIA has increased by 152% from ¥1.702 Billion RMB to ¥4.294 Billion RMB. The rental cost had the greatest increase of 22.6 times from ¥50 Million
RMB to ¥1.18 Billion RMB. The maintenance cost has also increased by 248% from ¥142 Million RMB to ¥495 Million RMB.

High rental cost is mainly due to the new terminal buildings and runways do not belong to BCIA, but its mother company, Capital Airport Holding Company (CAH). As a result, BCIA has to pay facility operating and rental fees to its mother company CAH under the current situation. To avoid the high fees it has to pay each year, BCIA decided to purchase back the new terminal 3 and the related facilities. The total cost of the purchase would be ¥26.9 Billion RMB. The source of finance is as follow:

<table>
<thead>
<tr>
<th>Source</th>
<th>Amount</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grants from Government</td>
<td>¥4.7 Billion RMB</td>
<td>17.47%</td>
</tr>
<tr>
<td>Beijing Capital Airport Group</td>
<td>¥3.8 Billion RMB</td>
<td>14.13%</td>
</tr>
<tr>
<td>European Investment Bank</td>
<td>¥2.4 Billion RMB</td>
<td>8.92%</td>
</tr>
<tr>
<td>Company Debt</td>
<td>¥11.1 Billion RMB</td>
<td>41.26%</td>
</tr>
<tr>
<td>Paid</td>
<td>¥4.9 Billion RMB</td>
<td>18.22%</td>
</tr>
</tbody>
</table>

*Data source: www.carnoc.com*

### 7. Summary

The construction of the third terminal building in Beijing Capital International Airport has met the air traffic requirement for Beijing Olympics and the rapid traffic growth through the airport in the short term. Advanced technology and energy efficient design has been integrated into the new terminal building. Different methods for ground transportation connecting the city center and the airport have also been designed together with the new terminal buildings. However, the cost of the terminal building, although comparatively reasonable, still has brought financial difficulty to the airport.
8. References

2. “Beijing Airport Terminal 3”, Martin Manning et. al
5. Website for the architect Norman Foster: http://www.fosterandpartners.com