Capacity Expansions of Beijing Capital International Airport

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Abstract

Three major capacity expansions at Beijing Capital International Airport are reviewed in the report. The designed capacity of each expansion is compared with the actual traffic in the following years. For most cases, the designed capacity was met earlier than expected as the traffic growth rate kept increasing. The airport throughput was limited by the designed capacity of the airport for relatively long periods. However, the airport managed to handle more traffic than designed. In the development history of Beijing International Airport, few practices of dynamic planning are found. Dynamic planning is suggested for further development.
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0.1 Introduction

Beijing Capital International Airport (BCIA) is the gateway of China and also the busiest airport in China. The traffic grows extraordinary fast over the past 10 years and it is the 8th in Top 30 Busiest Airport in the world by passengers in 2008 [1]. It is very important to plan the development of the airport appropriately to meet the increasing traffic demand. Several capacity expansions were performed in the past. The objective of this report is to review major capacity expansions by comparing the designed capacity of expansion projects with the actual traffic in the following years.

The report is organized as follows. Section 0.2 gives an introduction of Beijing Capital International Airport. The review and analysis of capacity expansions are presented in Section 0.3. Finally, Section 0.4 summarizes the report and gives the conclusions.

0.2 Beijing Capital International Airport

0.2.1 General

Beijing Capital International Airport is located northeast of Beijing, capital of People’s Republic of China. It is 25km away from the center of the city [3]. The airport is owned and operated by Beijing Capital International Airport Company Limited which is a state-controlled company. Some basic information about BCIA is listed in Table 1.

<table>
<thead>
<tr>
<th>Beijing Capital International Airport</th>
</tr>
</thead>
<tbody>
<tr>
<td>IATA Code</td>
</tr>
<tr>
<td>ICAO Code</td>
</tr>
<tr>
<td>Operator</td>
</tr>
<tr>
<td>Lat/Long</td>
</tr>
<tr>
<td>Elevation</td>
</tr>
<tr>
<td>Runways</td>
</tr>
<tr>
<td>Control Towers</td>
</tr>
<tr>
<td>Terminals</td>
</tr>
<tr>
<td>Traffic in 2008 [1]</td>
</tr>
</tbody>
</table>

Table 1: Basics of Beijing Capital International Airport
Beijing Capital International Airport is the main international airport of Beijing, and it is the largest and busiest airport in China. The traffic has grown fast in the past decade. In 2001, the annual passenger was 22 million and it is outside the 30 busiest airport ranking in the world by passenger volume. In 2008, the airport served 55 million passengers, which ranked 8th in the world by passenger volume. In terms of aircraft movements, the airport had become the 21st busiest airport in the world, handling 424,704 aircraft movements in 2008 [1].

![Figure 1: Beijing Capital International Airport General Layout](image)

### 0.2.2 Airside

Beijing Capital International Airport has 3 independent parallel runways (01/19, 18L/36R, & 18R/36L) as shown in Figure 2. The distance between the center of Runway 01/19 and the center of Runway 18L/36R is 1520 m, and the distance between the center of Runway 18L/36R and the center of 18R/36L is 1963 m. Thus, these 3 runways can be operated independently with each other. The specifics of each runway is summarized in Table 2.
<table>
<thead>
<tr>
<th>Direction</th>
<th>Dimensions</th>
<th>Surface</th>
<th>ICAO Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>01/19</td>
<td>3800 × 600</td>
<td>Concrete</td>
<td>F</td>
</tr>
<tr>
<td>18L/36R</td>
<td>3800 × 600</td>
<td>Asphalt</td>
<td>4E</td>
</tr>
<tr>
<td>18R/36L</td>
<td>3200 × 500</td>
<td>Asphalt</td>
<td>4E</td>
</tr>
</tbody>
</table>

Table 2: Runways Information of BCIA

The apron’s surface is 15.72 million $m^2$ and has 328 stands, including 8 stands for A380 [12]. The total perimeter of the airfield is 38.8 $km$ [12].
0.2.3 Landside

Beijing Capital International Airport has 3 terminals in operation. Terminal 1 covers an area of 60,000 m² and features 16 gates. The designed capacity of Terminal 1
is 9,000,000 passengers per year. Terminal 2, covering an area of 336,000 \( m^2 \) and equipped with state-of-the-art facilities, is able to handle 26,500,000 passengers yearly and 9,210 passengers at peak hours. Terminal 3 with 986,000 \( m^2 \) in total floor area became fully operational in 2008. It features a main passenger terminal (Terminal 3C), two satellite concourses (Terminal 3D and Terminal 3E) and five floors above ground and two underground. T3C handles domestic departure and arrival, and domestic and international baggage claim. T3E is for International departure and arrival. T3D was designed to be dedicated to Olympic and Paralympic charter flights. Terminal 3 was designed to have an annual capacity of 60,000,000 passengers.

Figure 3: Terminal 3 at Beijing Capital International Airport [7]

### 0.2.4 Airport Traffic

Beijing Capital International Airport is the gateway of China and the busiest airport in China. It serves 66 domestic and foreign airline companies, including 11 domestic companies and 55 foreign companies. There are more than 5,000 scheduled flights that connect Beijing to 88 domestic cities and 69 cities abroad. In 2008, the annual throughput of passengers was 55 million and the annual aircraft movements was more than 424 thousand.

The traffic at Beijing Capital International Airport has grown rapidly over the past decade. The traffic volume in 2008 is more than 3 times as it was in 1998 both in terms of passengers and aircraft movements (Data source [14]). Figure 4 shows
the traffic growth of Beijing Capital International Airport. The annual traffic has consistently grown since 1990, except the traffic dropped in 2003 when SARS was spreading in China.

The traffic varied at different times of the year at Beijing Capital International Airport. By plotting the aircraft movements and passengers of each month (Figure 5), one observes that in the summer (July to October) the airport usually experienced larger volume of traffic. The seasonal difference was more significant of the passenger throughput than the seasonal difference of aircraft movements.

The proportion of domestic traffic at Beijing International Airport has grown
gradually over the past 10 years. In 1998, domestic flights were around 75% of total flights, while domestic passengers were around 70%. By 2008, domestic flights increased to near 80% of total flights, and the domestic passengers were 78% of the total passengers. Figure 6 and Figure 7 shows the changes of domestic traffic over the past 10 years.

The average number of passengers per airplane also shifted over the past 10 years. Following the world airline industry’s trend, the average number of passengers per airplane increased from 100 to around 130. It is also worthy to note that the average number of passengers per airplane increased for domestic flights, while stayed relatively the same for international flights. These changes might be caused by the fact that the size of airplanes flying domestic routes increased, and the load factor of domestic flights became larger over the past 10 years. Figure 8 shows the average
number of passengers per airplane for domestic flights and for international flights over the past 10 years.

In summary, traffic at Beijing Capital International Airport grew significantly over the past 10 years. International traffic and domestic traffic increased at different growth rates. Domestic traffic showed a stronger increasing trend.
0.3 Review and Analysis of Airport Development

0.3.1 General Development History

Beijing Capital International Airport was first built in 1955 with only one runway and a small terminal building which is no longer a terminal now. After several capacity expansions, it now has 3 runways and 3 terminal buildings. Major capacity expansion projects has been summarized in the following chronology:

- 1955 New airport construction
- 1958 inauguration of operations
- 1966 Runway (18L/36R) extension (2500 m to 3200 m)
- 1980 Original runway (18L/36R) extension (3200 m to 3800 m)
  - New runway (18R/36L) built (3200 m)
  - New terminal (T1) built and open (60,000 m²)
- 1989 Terminal 1 expansion for Asian Games
- 1993 Terminal 1 further expansion (increased to 80,000 m²)
- 1999 Terminal 2 built and open (340,000 m²)
- 2004 Terminal 3 and new runway (01/19) construction
- 2008 Terminal 3 (990,000 m²) and runway 01/19 (3800 m) open; Beijing Olympic Games

0.3.2 Analysis of Major Capacity Expansions

A number of capacity expansion projects has been conducted in the past to accommodate the increasing traffic demand at Beijing Capital International Airport. Every capacity expansion project was the result of the airport planning process which anticipates possible future demands, considers many other factors, and then construct a development plan for the next several years. A number of researches were performed to evaluate the airport capacity and to investigate how to improve the capacity [16, 15, 9, 13]. This report focuses on three major capacity expansion conducted in the past and compares the designed capacity of each expansion with the actual traffic demand after the expansion. The runway capacity was re-calculated to compare with the designed capacity found in literature. Lessons learned from the
development of BCIA will be beneficial to future development of BCIA and other airports.

Capacity Expansion in 1980

Project Background  Before 1980, the airport had only one 2500 m runway, which is currently Runway 18L/36R. The first major capacity expansion was the construction of a new terminal building, a new runway, and the extension of the original runway. The expansion project was proved by the government in 1973, and finished in 1980. The new terminal, which is Terminal 1 in operation today, replaced the old terminal and was designed to be able to handle 3.5 million passengers per year. The new runway increased the runway capacity significantly, which made the runway capacity not a limiting factor of the airport capacity for the following 10 years.

Expansion Summary

<table>
<thead>
<tr>
<th>Expansion Project</th>
<th>1980: Original runway (18L/36R) extension, New runway (18R/36L), New terminal (T1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terminal capacity</td>
<td>3.5 million passengers per year</td>
</tr>
<tr>
<td>Runway capacity</td>
<td>250,000 – 357,000 movements per year</td>
</tr>
<tr>
<td>Expansion Project</td>
<td>1988-1993: Seven minor expansions</td>
</tr>
<tr>
<td>Terminal capacity</td>
<td>8 million passengers per year</td>
</tr>
</tbody>
</table>

Table 3: Summary of First Major Expansion Projects

Runway Capacity Calculation Although the two parallel runways were 1520m apart, they were not operated as independent runways by then. The independent operations of the two runways was not implemented until 2005 [18]. The author did not find the separation standards used and the traffic mix at BCIA in 1980s. The runway capacity can be estimated using today’s single runway separation standards and current traffic mix since the required separations should be larger in 1980s. The single runway capacity calculation can be found in Appendix .1. The capacity a single runway which is 56 aircraft per hour. So the two runway system without independent parallel operations would be slightly larger than 56. However, considering the traffic mix and operation practices in 1980, the capacity for this two runway system should be around 56, thus, the annual capacity is 250,000 aircraft movements.

Designed Capacity & Actual Traffic The runway capacity was not a crucial limiting factor during that period. The airport capacity was affected by the terminal
capacity. The new terminal was designed to have a capacity of 3.5 million aircraft per year. This designed capacity was reached soon after 4 years of Terminal 1 in operation. Several other projects was conducted to increase the capacity of the terminal building. Even though, the annual traffic reached the designed capacity after these expansions of 8 million passengers per year. The level of service from 1995 to 1998 degraded as a result of overloading. Figure 9 shows the annual traffic and the designed capacity in that period.

![Annual Traffic & Capacity at BCIA](image)

Figure 9: Annual Traffic & Designed Capacity Around First Expansion

The traffic growth rate at BCIA increased significantly from 1980 to 1998. The expansion project was probably designed based on historical growth rate. As a result, the capacity of the airport was reached much sooner than it was planned.

Capacity Expansion in 1999

**Project Background** In the second major capacity expansion, a new terminal building (Terminal 2) was built. The construction started in 1995 when the airport was under huge pressure of overloading. Terminal 2 became in operation in 1999 and the old terminal building, Terminal 1, was closed as the same time. The designed capacity of Terminal 2 was 26 million passengers per year by then. However, the capacity was reached again 3 years later. As a result, Terminal 1 was expanded and re-opened in 2004, which increased the capacity of the airport to 37 million passengers.
per year [8]. One year after the re-opening of Terminal 1, the independent parallel runway operation was implemented.

<table>
<thead>
<tr>
<th>Expansion Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Expansion Project</strong></td>
</tr>
<tr>
<td><strong>Terminal capacity</strong></td>
</tr>
<tr>
<td><strong>Expansion Project</strong></td>
</tr>
<tr>
<td><strong>Terminal capacity</strong></td>
</tr>
<tr>
<td><strong>Expansion Project</strong></td>
</tr>
<tr>
<td><strong>Runway capacity</strong></td>
</tr>
</tbody>
</table>

Table 4: Summary of Second Major Expansion Projects

**Runway Capacity Calculation** The independent operations of the two parallel runways were not conducted until 2005. During operation, one runway can be used for arrivals, while the other one for departures. In this configuration, the hourly throughput is 79 aircraft. Another configuration can be use both runways for alternating departures and arrivals, which gives the maximum hourly throughput of 112 aircraft. Thus, the capacity of the two independent runways is between 350,000 and 500,000 aircraft per year.

**Designed Capacity & Actual Traffic** The design capacity of Terminal 2 was 26 million aircraft per year when it was constructed. This design capacity of Terminal 2 was almost reached right after 2 years of its opening. SARS in 2003 reduced the traffic significantly and also the tension of overloading. In 2004, Terminal 1 was re-opened with an annual capacity of 9 million passengers. As a result, the total terminal capacity was 37 million passengers per year, which was still hard to meet the traffic demand. On the other hand, the runway capacity became a bottleneck with the increase of traffic. The implementation of independent operations of two runways solved the problem temporally. Figure 10 shows the annual traffic and the designed capacity in that period.

From the result of the second major expansion, one can conclude that Terminal 2 was designed too small the accommodate the traffic growth at BCIA. The development of the airport was always several steps after the demand growth.
The third major capacity expansion was both to meet the normal traffic growth and to prepare for the 2008 Olympic Games [7, 6]. The expansion included a new runway (01/19) and a new terminal building (Terminal 3) which was much larger than the other two terminal buildings. The construction started in 2004 and finished in 2008, 5 months before the Olympic Games. Terminal 3 with an area of 900,000$m^2$ was the largest airport terminal building in the world by then [2]. It is the second largest airport terminal in the world after Dubai International Airport’s Terminal 3 now. With the new terminal building and the third runway, the capacity of the airport increased to 82 million passengers and 600,000 aircraft movements per year. It is expected to meet the capacity by 2015.

### Expansion Summary

<table>
<thead>
<tr>
<th>Project</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008: New runway (01/19), New terminal (T3)</td>
<td>82 million passengers per year</td>
</tr>
<tr>
<td></td>
<td>600,000 movements per year</td>
</tr>
</tbody>
</table>

Table 5: Summary of Third Major Expansion Projects
Runway Capacity Calculation  The single runway capacity is obtained in Appendix .1. The throughput for one all arrivals, one all departures, and one alternating arrivals and departures is 134 aircraft per hour. If all three runways are used for alternating arrivals and departures, the maximum throughput is 167 aircraft per hour. So the annual aircraft movement capacity is between 610,000 and 759,000. Assume the average passengers per aircraft is around 120, based on the observation in Section 0.2, the annual passenger capacity is between 732 million and 911 million. Runway capacity matches terminal capacity if the average passengers per aircraft does not change.

Designed Capacity  This capacity expansion was the largest one in the development of BCIA. The planning was based on a traffic forecast of 82 million passengers in 2015. One can find that this is a more aggressive comparing to other forecasts applied in the past from Figure 11. Considering the increasing air transportation need and the current economic growth rate in China, this traffic forecast is reasonable.

Figure 11: Designed Capacity of Third Expansion

Summary of Capacity Expansions

Figure 12 shows the annual traffic over the past 30 years and the designed capacity of each major capacity expansion project. One can observe that the capacity expansion
projects were designed to increase the capacity in larger steps over years. However, the steps were still not large enough to catch up with the traffic growth. Most of the projects had a tendency of under estimation of traffic growth, except for the expansion in 2008. It is hard to conclude whether this expansion under-estimated or over-estimated the traffic growth now.

Figure 12: Annual Traffic and Designed Capacity of Major Expansions
0.4 Conclusions

Three major capacity expansions are reviewed in the report. The traffic always
grew faster than anticipated during the planning of each capacity expansion. The
airport throughput was limited by the designed capacity of the airport for relative
long periods. Level of service degraded when the airport was overloaded by traffic
demand.

Uncertainties in forecast is one of the biggest problems in airport development
planning. Dynamic planning is suggested to handle the uncertainties in the planning
process. However, in the development history of Beijing International Airport, few
practices of dynamic planning was found.

Future airport development options include expansion of existing airport or con-
struction of a second airport. Although traffic forecast will play an important role in
selection of which option, one should also consider the impacts of each option, which
impacts are more desirable, and also which option is more flexible to deal with the
changes in traffic forecast.
Bibliography


Appendices
.1 Single Runway Capacity at BCIA

Calculate the capacity envelop of a single runway at Beijing Capital International Airport under some simplified conditions.

The air traffic control rules in China classifies aircraft into 3 categories [11, 10]: Heavy: $MTOW \geq 136,000kg$ Medium: $7,000kg \leq MTOW < 136,000kg$

Small(Light): $MTOW < 7,000kg$

The approach speeds by aircraft type are estimated based on the approach speeds of Boeing’s aircraft published by the manufacture. A typical set of Runway Occupancy Time (ROT) on landing by aircraft type at BCIA is used. Traffic mix is obtained by sampling 2 daily flight schedules and matching the schedule with the type of aircraft [4]. All the parameters obtained are summarized in Table 6. The length of the final approach to the runway is 10 nautical miles. Table 7 shows the minimum separation requirements (in kilometers) between successive landing aircraft on final approach. In Table 7, rows indicate the leading aircraft and columns indicate the following aircraft. A safety buffer of 15 seconds is also considered. Through the standard calculation method ([17]), the maximum throughput for all arrivals is 31 aircraft per hour.

<table>
<thead>
<tr>
<th>Aircraft Type</th>
<th>Approach Speed (knots)</th>
<th>Mix (%)</th>
<th>ROT on landing (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>150</td>
<td>30</td>
<td>80</td>
</tr>
<tr>
<td>M</td>
<td>135</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>S</td>
<td>90</td>
<td>0</td>
<td>60</td>
</tr>
</tbody>
</table>

Table 6: Aircraft Characteristics

<table>
<thead>
<tr>
<th></th>
<th>H</th>
<th>M</th>
<th>S</th>
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<tbody>
<tr>
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<td>8</td>
<td>10</td>
<td>12</td>
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<tr>
<td>M</td>
<td>6</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>S</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 7: Minimum Separation Requirements (in km) Between Successive Landings

The minimum separation requirements (in seconds) between successive departing aircraft without considering Standard Instrument Departure are shown in Table (rows indicate the leading aircraft and columns indicate the following aircraft). The maximum throughput for all departures is 48 aircraft per hour. The free departures can be performed at 7 aircraft per hour.
Table 8: Minimum Separation Requirements (in seconds) Between Successive departures

<table>
<thead>
<tr>
<th></th>
<th>H</th>
<th>M</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>90</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>M</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>S</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
</tbody>
</table>

The capacity of alternating arrivals and departures is also estimated using simplified assumptions. The throughput for departures (arrivals) is 28 aircraft per hour. The maximum aircraft movements per hour is 56.

The capacity envelope is obtained by the above estimations as shown in Figure 13.

![Figure 13: Single Runway Capacity Envelope](image-url)