The New Airport for Berlin – Has Willy-Brandt (BBI) Airport enough Capacity for the Future?
A Simulation Approach

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Berlin, June 10th 2010
Personal Background

• Graduate in Business Administration and Engineering from Berlin School of Economics and Law (BSEL) and University of Applied Sciences Berlin
• 4th year in German Airport Performance Research Project at Berlin School of Economics and Law
• Conducted Benchmarking studies of European Airports and Airlines (75 Airports, 50 Airlines)
• Consultation in MIME Project, funded by EU Commission, studying Noise mitigation around airports, by market-based instruments
• Looking for new opportunities in Air Transportation Research & Development and PhD position
Contents

1. Berlin Airports Today and Tomorrow
2. European Comparisons to BBI
3. SIMMOD Study on Airside Capacity of BBI
4. Extension Plans for similar Airports
5. Vision
Plan of Berlin-Brandenburg International Airport
Why is Airport Runway Capacity so important

Economical Perspective:
- **Global Competition** of Regions which makes air interface vital
- **Attracting Airlines and Business**, Tourists and Transit Passengers
- **Reducing Costs** for Flying, by providing enough slots for demand and increasing future demand

Technical Perspective:
- **Operating at Practical/Sustainable Capacity** is important for Airport System Stability, Reliability (Scheduling!) and Service Quality (level-of-service (LOS) of e.g. 4 minutes of mean delay/flight)
- **Operating at Maximum capacity leaves no margin-of-safety** for unscheduled random events, e.g. weather (snow!), unscheduled flights (Business jets, Charter, General Aviation (GA)), emergency landing etc.
- **Delays increase exponentially at high utilization rates**
- **Knock-on delay effects make operating at airport costly for airlines**
Relationship between Demand, Capacity and Delay

• As airport demand increases towards its (ultimate) capacity, the airport system becomes congested and average delays per flight increase exponentially.

Modified from Horonjeff 2010, p.488
Berlin Airports today and tomorrow

- From 3 (Tegel (TXL), Schoenefeld (SXF), Tempelhof (THF) airports) make 1 (Willy-Brandt Airport (BBI))
- Existing airports (SXF and TXL) will be replaced fully by BBI on October 2011
- Political Dimension and Relevance for a study of BBI capacity and future development:

“When the Number of Runways at the existing Airports will be reduced from 4 to 2, Bottlenecks are bound to occur.”

(German Federal Transport Minister Peter Ramsauer, Tagesspiegel, June 7th, 2010)
## European Comparisons

- **Peer group of independent, far parallel-runway airports**
  (Separation of at least 1500 meters and alternate-mode operations)

- **Best Practices** with similar runway layout and highest productivity (2008) in comparison to BBI (SXF + TXL): **London-Heathrow and Munich**

- **BBI has the potential to rank third-biggest European airport** (before Palma-de-Mallorca (PMI) and Oslo (OSL)) in peer group by 2012

<table>
<thead>
<tr>
<th>Airport</th>
<th>Annual PAX (million)</th>
<th>Annual Flights (thousand)</th>
<th>PAX per Flight</th>
<th>Peak Hour Throughput</th>
</tr>
</thead>
<tbody>
<tr>
<td>London-Heathrow</td>
<td>67.2</td>
<td>473</td>
<td>142</td>
<td>103</td>
</tr>
<tr>
<td>Munich</td>
<td>34.5</td>
<td>409</td>
<td>84</td>
<td>93</td>
</tr>
<tr>
<td>BBI (TXL+SXF 2008)</td>
<td>21.2</td>
<td>212</td>
<td>100</td>
<td>48</td>
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<tr>
<td><strong>BBI Planned Final 2023</strong></td>
<td><strong>30</strong></td>
<td><strong>301-329</strong></td>
<td><strong>100-91</strong></td>
<td><strong>90</strong></td>
</tr>
<tr>
<td>(Planning Permission 2004)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>BBI Sustainable Final at 2024</strong></td>
<td><strong>28.1</strong></td>
<td><strong>303</strong></td>
<td><strong>93</strong></td>
<td><strong>76</strong></td>
</tr>
<tr>
<td>(60% growth from 2008 at 3%; SIMMOD study 2010)</td>
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</tr>
</tbody>
</table>
BBI Study Background

- Study prepared for International Conference on Operations Research "Mastering Complexity“ Munich 2010 with Prof. Joachim Daduna (BSEL)
- Full study available in September 2010
- Software: GUI: Visual SIMMOD
  Engine: FAA SIMMOD Engine
- Flight schedule data: Flightstats.com
- Basic Information: Official Planning Permission Documents for BBI

- Sensitivity Analysis towards 6 Scenarios with different traffic mixes (shares of aircraft wake turbulence classes: Small (<7 tons MTOW), Large (7-136 tons MTOW) and Heavy (>136 tons MTOW))
- 11 growth scenarios (-20%,0%,20%,40%,...,200%) at 10 iterations each
- Based on predefined Design Peak Day 2008 (June 26th 2008)
# Simulated Scenarios and Traffic Mixes

<table>
<thead>
<tr>
<th>Turbulence Class</th>
<th>Airport</th>
<th>Share</th>
<th>Flights</th>
<th>Airport</th>
<th>Share</th>
<th>Flights</th>
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<th>Airport</th>
<th>Share</th>
<th>Flights</th>
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<tbody>
<tr>
<td></td>
<td>SXF</td>
<td></td>
<td></td>
<td>TXL</td>
<td></td>
<td></td>
<td>BBI</td>
<td></td>
<td></td>
<td>BBI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HEAVY</td>
<td>0%</td>
<td>3%</td>
<td>12</td>
<td>2%</td>
<td>12</td>
<td>5%</td>
<td>32</td>
<td>15%</td>
<td>95</td>
<td>5%</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>LARGE</td>
<td>100%</td>
<td>155</td>
<td>95%</td>
<td>454</td>
<td>96%</td>
<td>609</td>
<td>95%</td>
<td>603</td>
<td>80%</td>
<td>508</td>
<td>84%</td>
<td>533</td>
</tr>
<tr>
<td>SMALL</td>
<td>0%</td>
<td>3%</td>
<td>14</td>
<td>2%</td>
<td>14</td>
<td>0%</td>
<td>0</td>
<td>5%</td>
<td>32</td>
<td>11%</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>Sum</td>
<td>100%</td>
<td>155</td>
<td>100%</td>
<td>480</td>
<td>100%</td>
<td>635</td>
<td>100%</td>
<td>635</td>
<td>100%</td>
<td>635</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>Mix Index (MI)</td>
<td>100%</td>
<td>102%</td>
<td>102%</td>
<td></td>
<td></td>
<td></td>
<td>110%</td>
<td>125%</td>
<td></td>
<td>99%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**MI = 3 \times (\% \text{HEAVY}) + (\% \text{LARGE})**
BBI SIMMOD Study Assumptions

- Realistic assumptions resulting from combined actual traffic data of Berlin Tegel (TXL) and Schoenefeld (SXF) airports and Planning Permission documents:
  - Delay per Flight will be Key Performance Indicator
  - Schedule
  - Traffic Mix
  - Runway Layout
  - Parking Stands
  - Punctuality & other Random Distributions
  - 20 Additional Business Jet or GA Flights in morning & evening Peaks (7-12 & 15-20; Scenario 0a)
Presenting Interim Results

- **Scenario 0** (baseline, 2 independent parallel runways, current SXF+TXL=BBI traffic mix):

- Simulated throughput Capacity of 82-84 Flights per hour at 120-140%! Further increase of traffic resulted in grid locking queues and therefore flight cancellations.

- Sustainable long-term throughput/capacity of 76 Flights per hour! (1 operation every 47 seconds) The animation proves this.

- Demand higher than Capacity at 60% Growth, based on 2008 busy day schedule and Level-of-Service of 5-6 minutes of Avg. Delay per flight.

- Delays will increase exponentially beyond 60% growth.

- Upper and lower boundaries of historic growth rates at TXL and SXF underline the assumption that demand=capacity reached between 2016-2024 (at 3-6% annual growth).

- Each 20% growth increment results in doubling of daily delays.
Results Scenario 0: Simulated Peak Throughput at BBI

Projected Growth of Traffic at Berlin-Brandenburg Airport in Comparison to Runway Capacity (Scenario 0: "Nullszenario")

- Demand and Capacity in Flights per hour
- Projected Growth of Traffic
- Comparison to Runway Capacity (Scenario 0: "Nullszenario")

Graph showing demand and capacity in flights per hour for different scenarios ranging from 0% to 160%.

Legend:
- Hourly Capacity
- Hourly Demand
- Maximum Capacity SIMMOD
- Maximum Capacity Planning Permission 2023
Results: Simulated Delays at BBI:

- **Scenario 0**
  (*Note: 42€ cost per minute of delay (Eurocontrol 2009: “Standard Inputs for CBA Analyses”)
  
<table>
<thead>
<tr>
<th>Growth from Baseline</th>
<th>Daily Flights</th>
<th>Peak Hour Demand</th>
<th>Hourly Capacity</th>
<th>Mean Delay per Flight</th>
<th>Daily Delay Minutes</th>
<th>Daily Delay Costs at 42€ * (without cancellation costs)</th>
<th>Cancellations</th>
</tr>
</thead>
<tbody>
<tr>
<td>-20%</td>
<td>511</td>
<td>40</td>
<td>40</td>
<td>1.1</td>
<td>543</td>
<td>EUR 22,806</td>
<td>0</td>
</tr>
<tr>
<td>0%</td>
<td>635</td>
<td>48</td>
<td>48</td>
<td>1.4</td>
<td>887</td>
<td>EUR 37,254</td>
<td>0</td>
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<tr>
<td>20%</td>
<td>758</td>
<td>55</td>
<td>54</td>
<td>2.3</td>
<td>1760</td>
<td>EUR 73,920</td>
<td>0</td>
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<tr>
<td>40%</td>
<td>886</td>
<td>69</td>
<td>71</td>
<td>3.7</td>
<td>3287</td>
<td>EUR 138,054</td>
<td>0</td>
</tr>
<tr>
<td>60%</td>
<td>1012</td>
<td>78</td>
<td>76</td>
<td>5.9</td>
<td>5955</td>
<td>EUR 250,110</td>
<td>0</td>
</tr>
<tr>
<td>80%</td>
<td>1145</td>
<td>94</td>
<td>80</td>
<td>11.5</td>
<td>13223</td>
<td>EUR 555,366</td>
<td>0</td>
</tr>
<tr>
<td>100%</td>
<td>1270</td>
<td>90</td>
<td>82</td>
<td>21.2</td>
<td>26968</td>
<td>EUR 1,132,656</td>
<td>1</td>
</tr>
<tr>
<td>120%</td>
<td>1400</td>
<td>96</td>
<td>82</td>
<td>26.8</td>
<td>37501</td>
<td>EUR 1,575,042</td>
<td>134</td>
</tr>
<tr>
<td>140%</td>
<td>1517</td>
<td>98</td>
<td>84</td>
<td>27.4</td>
<td>41538</td>
<td>EUR 1,744,596</td>
<td>440</td>
</tr>
<tr>
<td>160%</td>
<td>1639</td>
<td>110</td>
<td>83</td>
<td>58.2</td>
<td>95364</td>
<td>EUR 4,005,288</td>
<td>807</td>
</tr>
</tbody>
</table>
Results: Simulated Delays at BBI

Average Delay per Flight from Simulation of BBI Baseline Scenario 0

Avg. Delay = 0.0906e^{0.0572x}
R² = 0.9634

Avg Delay = 0.1624e^{0.0036x}
R² = 0.9883

Expon. (Average Delay per Daily Flights)
---
Expon. (Average Delay per Peak Hour Flights)

Average Delay per Daily Flights
---
Average Delay per Peak Hour Flights

sustainable
---
Not sustainable

Peak Hourly Flights
---
Daily Flights

Daily Flights
---
Average Delay per Flight
Capacity limits reached at BBI

- The Sustainable Capacity of 76 Flights per Hour and 60% growth can be reached after:
  - 16 years at 3% average growth of traffic (2008-2024) \((1 + r)^{16} - 1 = (1 + 0.03)^{16} - 1 = 60\%\)
  - 12 years at 4% average growth of traffic (2008-2020) \((1 + r)^{12} - 1 = (1 + 0.04)^{12} - 1 = 60\%\)
  - 10 years at 5% average growth of traffic (2008-2018) \((1 + r)^{10} - 1 = (1 + 0.05)^{10} - 1 = 63\%\)
  - 8 years at 6% average growth of traffic (2008-2016) \((1 + r)^{8} - 1 = (1 + 0.06)^{8} - 1 = 59\%\)

- The planning timeline for a third runway at BBI depends on the economic developments in the region in the next months and years.
- We must start discussing a 3rd runway at BBI in 2014 the latest, as a result from Scenario 0 (3% growth), if 10 years until realisation are considered.
- Legal, political and environmental approval time will increase further in the future, so do the opportunity costs from building a runway too late.
Growth of Berlin Airports

Source: Eurostat
Trends of Annual and Peak Hour Flights in Europe

Trends of Annual flights to Design Peak Hour Flights and Passengers
(Data from 60 European Airports in 2007)

\[ y = 0.376x^{0.917} \]
\[ R^2 = 0.914 \]

\[ y = 32.99x^{0.976} \]
\[ R^2 = 0.918 \]
Trends of Peak Hour and Annual Flights in Europe

Trends of Peak Hour Flights to Annual Passengers and Flights

\[ y = 0.303x^{1.046} \]
\[ R^2 = 0.780 \]

\[ y = 4.059x^{0.996} \]
\[ R^2 = 0.914 \]
Approximation Functions established from 60 EU airports

If Annual Flights are known from forecasts:
1. Peak Hour Flights = 0.376*Annual Flights (in thousand)^0.917
2. Peak Hour Passengers = 32.99*Annual Flights (in thousand)^0.976

If Peak Hour Flights are known from forecasts or simulations:
3. Annual Flights in thousand = 4.059*Peak Hour Flights^0.996
4. Annual Passengers in million = 0.303*Peak Hour Flights^1.046

Source: Bubalo 2010
Testing Assumptions Using Approximation Equations

- BBI Planning Permission Forecast 2023 (2004):
  - 355,000 Flights per year and 90 Movements per hour.
    With 1. & 2.: 355,000 annual flights -> 82 Peak Hour Flights and 10,173 Peak Hour Passengers
    With 3. & 4.: 90 Peak Hour Flights -> 359,000 Annual Flights and 33.5 million Passengers

- BBI SIMMOD Study (2010):
  - Sustainable Capacity at 76 Flights per hour after 60% growth
    With 3. & 4.: 76 Peak hour flights -> 303,000 flights and 28.1 million PAX
  - Capped Capacity at 82-84 Flights per hour after 100%
    With 3. & 4.: 82 Peak Hour flights -> 327,000 Annual Flights and 30.4 million annual Passengers
Resulting BBI Forecasts based on 2008 traffic schedule

<table>
<thead>
<tr>
<th>Airport</th>
<th>Annual PAX (million)</th>
<th>Annual Flights (thousand)</th>
<th>PAX per Flight</th>
<th>Peak Hour Flights</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>BBI 2008 (TXL+SXF 2008)</td>
<td>21.2</td>
<td>212</td>
<td>100</td>
<td>48</td>
<td>48</td>
</tr>
<tr>
<td>BBI Planned Capacity 2023</td>
<td>30</td>
<td>301-355</td>
<td>100-85</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>BBI Sustainable Capacity 2024 (60% growth</td>
<td>28.1</td>
<td>303</td>
<td>93</td>
<td>76</td>
<td>82</td>
</tr>
<tr>
<td>2008 at 3%; this study)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BBI Sustainable Capacity 2018 (60% growth</td>
<td>28.1</td>
<td>303</td>
<td>93</td>
<td>76</td>
<td>82</td>
</tr>
<tr>
<td>2008 at 5%, this study)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BBI Maximum Capacity (100%)</td>
<td>33.5</td>
<td>359</td>
<td>93</td>
<td>90</td>
<td>82</td>
</tr>
</tbody>
</table>
How far should we think for the future of BBI?

• Should we develop a vision for an ultimate stage of development for BBI, despite of political concerns?
• Runway configuration Master plan of London-Heathrow after 1945
The World Busiest Airport

- Atlanta Int. (2008): 88 million passengers, 970,235 flights

- How far is too far?
How far should we think for the future of BBI?

• Regional and airport planners must be creative and realistic in their forecasts and long term views.
• Runways take 10 years of planning, approval and construction time (economical life 40-100 years)
• Noise and local air quality increasingly important, but very difficult to quantify & monetize for compensations
• The future is uncertain, but market outlooks predict further growth of air transportation
• We can learn from other airports already:
  – London Heathrow in 2010: saturated most of the day
  – Munich in 2010: congested during daily peak hours
• Possible near Future for BBI? ->
Current Plan London Heathrow (2020?)

- Strong public opposition against 3rd runway
- Environmental and Legal battle will be endless
Current Plans for Munich (2020?)

- Munich 2 had been under restrictions from 1993 on.
- 3rd runway is strongly opposed, but will be built
Vision

• Commitment and Continuing Discussion towards aviation needs (including General and Business Aviation).
• Neighbours of airports should be kept well informed about future developments, even if 20 years or more in advance.
• Master plans must present long-term views with high and low growth forecasts.
• Runways are long-term investments, which are depreciated over 50 to 100 years, so long-sided visions needed.
• Apart from looking at runway capacity, environmental capacity could become more critical in the future.
• Simulation is the tool to make airport capacity planning and (noise) impact forecasts, realistic, transparent, safe and fair.
Thank you for your attention! Questions?

Suggestions and Comments are welcome.

Full study available after:

International Conference
OPERATIONS RESEARCH
MUNICH 2010

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