EQUITY & EFFICIENCY
In Search of METRICS

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Moving Metrics
NEXTOR SEMINAR
January 29, 2004
Asilomar, California
Framework for Assessing Equity

Investment by Agent

Returns to Agent

Deployment

Impacts

Metrics

Redistribution

Airline

Airport

Pax.

Gov.

Others
Two Equity issues

• Equity in A Queue.
  – Inherent Distribution of Delay in a Queue
  – Equity Effects of Queue Management Efficiency
  – Intra- and Inter-Airline Impacts
  – Unit Costs to different type of users

• Differential Impacts of System Investment
Bad Day at EWR May 24, 1999
Equity in Queues

$d_2$

$fifo$

$scrambled$

$d_1$
Measuring Queue Disruption

### fifo

<table>
<thead>
<tr>
<th>h</th>
<th>s</th>
<th>d₁</th>
<th>d₂</th>
<th>d_{avg}</th>
<th>c.v.</th>
<th>d₁</th>
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### Scrambled

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**Good Day at EWR**

\[ \text{d}_{\text{avg}} = 57.9 \]
\[ \sigma = 49.6 \]
\[ \text{c.v.} = 42.5 \]

\[ \text{d}_{\text{avg}} = 57.9 \]
\[ \sigma = 56.8 \]
\[ \text{c.v.} = 55.7 \]

C.V. Ratio = 1.31
Bad Day at EWR

\[ d_{\text{avg}} = 105.1 \]
\[ \sigma = 46.6 \]
\[ \text{c.v.} = 20.6 \]

C.V. Ratio = 2.50
The Costs Of Delay

• Account for different types of delays (where, when)
• Consider distributional effects
  • Technologies may shift to whom delay occurs
  • Different user types value delay differently
• Nonlinear effect of duration of delay (e.g. issue of buffer)
Case Study Using ITWS

• Queuing Analysis of departures
• Uses MIT/LL Estimates of Capacity Gain
• Simulates Queue Evolution
  – Delay by Aircraft Type
  – Delay by Flight Type
  – Delay by Airline

• Summary by Airline:
## Delay Segmentation

### Table 1: Calculations for Delay to Operators

<table>
<thead>
<tr>
<th></th>
<th>On ground – engines off</th>
<th>On Ground - engines on</th>
<th>Airborne Delay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than buffer*</td>
<td>None</td>
<td>Idling aircraft costs</td>
<td>Airborne aircraft costs</td>
</tr>
<tr>
<td>More than buffer**</td>
<td>Crew costs</td>
<td>Idling aircraft costs + Crew costs</td>
<td>Airborne aircraft costs + Crew costs</td>
</tr>
</tbody>
</table>

* If the airborne time is less than the planned OAG flight schedule (minus buffer, taxi in/out times), then saved delay is multiplied by the crew costs to counterbalance the cost of the delay taken on the ground.

** If the delay is more than the connection time, an administrative cost is added per connecting passenger.
Unit Costs of Delay

• Assumptions
  – A buffer of 10 minutes for flights longer than 50 minutes gate-to-gate
  – A slack time of 20 minutes in turn-around times
  – A slack time of 45 minutes for connections
  – 45 minutes maximum engines-on ground delay
## Unit Costs of Delay

### Table 2: Value for Delay to Operators (dollars per minute)

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<tr>
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<th>On Ground - engines on</th>
<th>Airborne Delay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than buffer</td>
<td>$0</td>
<td>$5.36</td>
<td>$31.58</td>
</tr>
<tr>
<td>More than buffer</td>
<td>$22.38*</td>
<td>$27.74</td>
<td>$53.96</td>
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</tbody>
</table>

*Also used for Taxi delay greater than 45 minutes and the crew time savings when the aircraft flies faster than expected.

Differentiating The Costs Of Delay

• Need to capture how the different stakeholders might value delay, e.g.:
  – Under “degraded operations”, hubbing airlines with little or no slack or buffer times may be more adversely affected because of delay propagation
  – Under “normal operations, airlines with limited buffers will have very little time wasted on the ground
  – Technological improvements may benefits users differently