Effect of radii of exemption on GDPs with operating cost based cruise speed reduction

Case study: Chicago O’Hare International Airport

Luis Delgado

12/06/2013
Speed reduction / speed control

D. De Smedt, J. Bronsvoort and G. McDonald,
Controlled Time of Arrival Feasibility Analysis

J. C. Jones, D. J. Lovell and M. O. Ball,
En Route Speed Control Methods for Transferring Terminal Delay

C. Wynnyk, M. Balakrishna, P. MacWilliams and T. Becher,
2011 Trajectory Based Operations Flight Trials
Delay and ground delay programs

- GDP definition time
- GDP start time
- Aggregate arrival demand
- Program Airport Acceptance Rate (PAAR)
- Mean Nominal Airport Acceptance Rate (AAR)
- GDP end time
Radius of exemption / program scope
Radius of exemption

Large radius

Aircraft included

Average delay

Holding delay

Realise delay ahead

Delay recovered
Radius of exemption

**Short radius**
- Aircraft included
- Average delay
- Holding delay
- Realise delay ahead
- Delay recovered
Radius of exemption

**Large radius**
- Aircraft included: Up
- Average delay: Down
- Holding delay: Down
- Realise delay ahead: Up
- Delay recovered: Down

**Short radius**
- Aircraft included: Down
- Average delay: Up
- Holding delay: Up
- Realise delay ahead: Down
- Delay recovered: Up
Delay management by speed reduction

ETD \quad \text{ETTA}

delay

\begin{align*}
\text{CTD} & \quad V_0 \\
\text{delay'} & \quad V_{\text{red}} \quad V_0
\end{align*}

Regulation Cancellation

\begin{align*}
\text{CTD'} & \quad CTA \\
\text{CTA} & \quad CTA
\end{align*}
Contents

1. Equivalent speed concept
2. Simulation set up
3. Results
4. Conclusions and further research
Contents

1. Equivalent speed concept
2. Simulation set up
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Equivalent speed concept

- Specific Range

\[
SR = \frac{GS}{\dot{m}_{fuel}} = \frac{V + w}{\dot{m}_{fuel}} = SR_{air} + \frac{w}{\dot{m}_{fuel}} \left( \frac{NM}{kg} \right)
\]

![Diagram showing fuel flow (kg/h) versus aircraft true air speed (kt)]
Equivalent speed concept

• Specific Range

\[ SR = \frac{GS}{\dot{m}_{fuel}} = \frac{V + w}{\dot{m}_{fuel}} = SR_{air} + \frac{w}{\dot{m}_{fuel}} \left( \frac{NM}{kg} \right) \]
Equivalent speed concept

- Specific Range

\[ SR = \frac{GS}{\dot{m}_{fuel}} = \frac{V + w}{\dot{m}_{fuel}} = SR_{air} + \frac{w}{\dot{m}_{fuel}} \left( \frac{NM}{kg} \right) \]
Contents

1. Equivalent speed concept
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Analysed ground delay programs

- **2006 GDPs**

<table>
<thead>
<tr>
<th>Airport</th>
<th>Delay assigned (min)</th>
<th>% GDPs over total</th>
<th>Number of GDPs defined</th>
<th>Average number of aircraft per GDP</th>
<th>Average delay per aircraft (min)</th>
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</thead>
<tbody>
<tr>
<td>ORD</td>
<td>4,533,341</td>
<td>25,14</td>
<td>120</td>
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<td>EWR</td>
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<td>PHL</td>
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<td>BOS</td>
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<td>SFO</td>
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<td>131</td>
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<td>JFK</td>
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<td>3,27</td>
<td>40</td>
<td>282</td>
<td>52</td>
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</tbody>
</table>
Analysed ground delay programs

- *K*-means clustering – 2006 GDPs

<table>
<thead>
<tr>
<th>GDP group</th>
<th>Number of GDPs</th>
<th>Filed time</th>
<th>Starting time</th>
<th>Planned ending time</th>
<th>Cancellation time</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>All-day GDPs</em></td>
<td>65</td>
<td>8h28</td>
<td>9h52</td>
<td>22h19</td>
<td>20h13</td>
</tr>
<tr>
<td><em>Afternoon GDPs</em></td>
<td>43</td>
<td>14h58</td>
<td>15h26</td>
<td>22h15</td>
<td>19h58</td>
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<tr>
<td><em>Early cancel GDPs</em></td>
<td>12</td>
<td>7h49</td>
<td>9h02</td>
<td>18h33</td>
<td>9h53</td>
</tr>
</tbody>
</table>

AAR – 112 aircraft/hour
PAAR – 84 aircraft/hour
Analysed ground delay programs

- Effects of radius of exemption
  - NAS
  - 1,200 NM
  - 800 NM
  - 400 NM
Traffic

- August 24th and 25th 2005
- Airbus performances
- Typical cost indexes and payloads

No Wind Scenarios

<table>
<thead>
<tr>
<th>Aircraft type</th>
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</thead>
<tbody>
<tr>
<td>A300</td>
</tr>
<tr>
<td>A319</td>
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<td>A320</td>
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<td>A321</td>
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<tr>
<td>A330</td>
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<tr>
<td>A340</td>
</tr>
</tbody>
</table>

European Low Fares Association Members. 2008. *Members’ statistics*
Airbus. 1998. *Getting to grips with the cost index*
Demand and airborne delay computation

- **Initial demand**: 2,846 flights
- **Airbus PEP**: 2,370 flights (83.3%)
- **Nominal flight plans**
- **FACET**
  - Maximum airborne delay
  - Arrival demand
Demand and airborne delay computation

FACET

- Maximum airborne delay
- Arrival demand

Initial demand
Nominal flight plans
Airbus PEP
Demand and airborne delay computation

Nominal flight parameters

- Cruise Initialisation (FL, V0, W0)
  - Compute Fuel Flow and update weight
  - Compute and update V_eq

FACET
- Maximum airborne delay
- Arrival demand

Cruise Initialisation (FL, V0, W0)
- Compute Fuel Flow and update weight

V0

V_eq
Simulation architecture

- GDP characteristics
- Initial demand
- Maximum airborne delay
- RBS
- Delay assignment and division
Contents

1. Equivalent speed concept
2. Simulation set up
3. Results
4. Conclusions and further research
Delay recovered

- As a function of cancellation time
Potential airborne delay

• Simulated traffic August 24th and 25th 2005

• Maximum airborne delay distribution
Effect of radius of exemption

• Delay division
Effect of radius of exemption

• Delay division
Effect of radius of exemption

- Aircraft affected
Effect of radius of exemption

- Extra delay recovered

All-day
Effect of radius of exemption

- Delay recovered at average cancellation time
Effect of radius of exemption

• Aggregated extra delay recovered at average cancellation time

<table>
<thead>
<tr>
<th>Airport</th>
<th>400 NM</th>
<th>800 NM</th>
<th>1,200 NM</th>
<th>No radius</th>
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<tbody>
<tr>
<td>ORD</td>
<td>3,246</td>
<td>23,168</td>
<td>34,753</td>
<td>48,685</td>
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</tbody>
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Effect of radius of exemption

Larger radius
- Aircraft included: Up
- Average delay: Down
- Holding delay: Down
- Realise delay ahead: Up
- Delay recovered: Down

Shorter radius
- Aircraft included: Down
- Average delay: Up
- Holding delay: Up
- Realise delay ahead: Down
- Delay recovered: Up

ground/airborne speed up
Contents

1. Equivalent speed concept
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Conclusions and further research

• Trade-off associated with the definition of radius
• Airborne speed reduction allows using higher radii
• A less costly regulation can be implemented
• Larger radii implies longer distance and lower average assigned delay
• More airborne delay and potentially more delay recovered
• Location of the airport has high impact on the strategy
• Different scenarios should be assessed and other parameters such as wind
<table>
<thead>
<tr>
<th>TIME</th>
<th>FLIGHT</th>
<th>DESTINATION</th>
<th>GATE</th>
<th>REMARKS</th>
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<tbody>
<tr>
<td>11:15</td>
<td>UA411</td>
<td>SAN FRANCISCO</td>
<td>A27</td>
<td>DELAYED</td>
</tr>
<tr>
<td>11:20</td>
<td>LH417</td>
<td>CHICAGO</td>
<td>B18</td>
<td>DELAYED</td>
</tr>
<tr>
<td>11:30</td>
<td>AA204</td>
<td>NEWARK</td>
<td>A26</td>
<td>DELAYED</td>
</tr>
<tr>
<td>11:45</td>
<td>DL616</td>
<td>BARCELONA</td>
<td>C11</td>
<td>ON TIME</td>
</tr>
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<td>11:50</td>
<td>AF204</td>
<td>PARIS CDG</td>
<td>C41</td>
<td>ON TIME</td>
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<tr>
<td>12:00</td>
<td>AC702</td>
<td>NEW YORK JFK</td>
<td>B09</td>
<td>DELAYED</td>
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<tr>
<td>12:15</td>
<td>CO101</td>
<td>SAN JOSE</td>
<td>A18</td>
<td>ON TIME</td>
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<tr>
<td>12:25</td>
<td>DL333</td>
<td>ATLANTA</td>
<td>C03</td>
<td>DELAYED</td>
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<tr>
<td>12:45</td>
<td>JB226</td>
<td>CINCINNATI</td>
<td>B38</td>
<td>ON TIME</td>
</tr>
<tr>
<td>12:55</td>
<td>UA112</td>
<td>PHILADELPHIA</td>
<td>B07</td>
<td>ON TIME</td>
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<tr>
<td>13:10</td>
<td>BA651</td>
<td>LONDON</td>
<td>A02</td>
<td>ON TIME</td>
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<tr>
<td>13:20</td>
<td>AA651</td>
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<td>13:30</td>
<td>AC204</td>
<td>TORONTO</td>
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</table>