The challenge of ATM performance measurement

Cook, A.J.

Presented at the Global Workshop on Aviation System Performance, Tianjin, China, 21 - 23 July 2016.

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The challenge of ATM performance measurement

Dr Andrew Cook
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University of Westminster, London
Overview

- Comparing three regions
- New metrics & sampling insights
- Multiple targets
- Challenges & opportunities
Acknowledgments

SESAR 2020 Exploratory Research: Research & Innovation Action. University of Westminster (coordinator), Innaxis, EUROCONTROL, Icelandair, Norwegian Air Shuttle, SWISS, Belgocontrol.

Comparing three regions
## Comparing three regions

<table>
<thead>
<tr>
<th></th>
<th>Europe</th>
<th>US</th>
<th>China</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Airline liberalisation</strong></td>
<td>▪ within EU: main change - deregulation int. routes, 1993</td>
<td>▪ major industry liberalisation first started in US, 1978</td>
<td>▪ official separation military jurisdiction, 1980</td>
</tr>
<tr>
<td></td>
<td>▪ beyond EU: series bilaterals and ‘open sky’ agreements</td>
<td>▪ major EU-US multilateral agreement, 2008</td>
<td>▪ merged into three large airline groups, 2002</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>▪ regionals emerged essentially as supplementary</td>
</tr>
<tr>
<td><strong>Major operators, alliances, ownership</strong></td>
<td>Lufthansa Group (Star Alliance)</td>
<td>American Airlines (oneworld)</td>
<td>Air China (Star Alliance)*</td>
</tr>
<tr>
<td></td>
<td>Ryanair (LCC; no global alliance)</td>
<td>Delta (SkyTeam)</td>
<td>China Eastern (SkyTeam)*</td>
</tr>
<tr>
<td></td>
<td>IAG (oneworld)</td>
<td>Southwest (LCC; no global alliance)</td>
<td>China Southern (SkyTeam)*</td>
</tr>
<tr>
<td></td>
<td>Air France-KLM (SkyTeam)</td>
<td>United Airlines (Star Alliance)</td>
<td>Hainan Airlines (no global alliance)†</td>
</tr>
<tr>
<td></td>
<td>wholly/majority private holdings</td>
<td>public companies</td>
<td>* majority state shareholdings</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>† largest privately-owned airline</td>
</tr>
<tr>
<td><strong>Airport strategic schedule control</strong></td>
<td>yes</td>
<td>no</td>
<td>yes</td>
</tr>
</tbody>
</table>
# Comparing three regions

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<thead>
<tr>
<th></th>
<th>Europe</th>
<th>US</th>
<th>China</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ATFM service provision</strong></td>
<td>41 states (EUROCONTROL)</td>
<td>Federal Aviation Administration</td>
<td>Air Traffic Management Bureau (CAAC)</td>
</tr>
<tr>
<td></td>
<td>63 en-route centres</td>
<td>20 air route traffic ctrl centres</td>
<td>7 ATFM regions</td>
</tr>
<tr>
<td><strong>Primary management</strong></td>
<td>at-gate</td>
<td>airborne</td>
<td>airborne</td>
</tr>
<tr>
<td><strong>MIT</strong></td>
<td>very limited</td>
<td>yes (-&gt;TBM)</td>
<td>yes</td>
</tr>
<tr>
<td><strong>Special use airspace</strong></td>
<td>core</td>
<td>coast</td>
<td>core</td>
</tr>
<tr>
<td><strong>ATFM / AO/ airport CDM</strong></td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>
Comparing three regions

• Common
  – mergers into airline groups; global alliance affiliations

• Europe and US
  – established free-markets
  – growth in LCCs; demarcation breaking down in Europe

• China
  – from fully planned, to more market economy
  – competition, e.g. between three largest groups; few LCCs

• ATFM, mainly similarities; key characterising features:
  – Europe: fragmentation
  – US: large weather systems (airport flows)
  – China: special use airspace
## Comparing three regions

<table>
<thead>
<tr>
<th>Data level by region</th>
<th>Europe</th>
<th>US</th>
<th>China</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focus on arrival or departure delay</td>
<td>departure</td>
<td>arrival</td>
<td>arrival</td>
</tr>
<tr>
<td>Delay threshold</td>
<td>≥ 5 mins</td>
<td>≥ 15 mins</td>
<td>&gt; 5 mins</td>
</tr>
<tr>
<td>Main delay causes reported</td>
<td>airline, weather, ATFM, weather, ATFM, airports, ATFM, en-route, reactionary</td>
<td>airline, weather, ATFM</td>
<td>airline, weather, ATFM</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>security</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>military</td>
</tr>
</tbody>
</table>
## Comparing three regions

(2014)

<table>
<thead>
<tr>
<th></th>
<th>Europe</th>
<th>US</th>
<th>China</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total airports</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total* pax (m)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total* flights (m)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delayed ≥ 5 mins</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delayed ≥ 15 mins</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avg. delay (mins)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reactionary delay</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ATFM delay</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cancelled</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* International and domestic

Sorry, table not publicly available just yet

The challenge of ATM performance measurement
Global Workshop on Aviation System Performance 2016

21-23 July 2016
Tianjin, China
New metrics & sampling insights

Do the top 30 airports give us 80% of the metric?
What does the shape of the curve look like there?
New metrics & sampling insights

• Primary ATM data sources (don’t always agree)
  – pure trajectory (radar track) data
  – network manager (e.g. ATFM) delay data, with causes
  – airline data (e.g. delay & cancellation) (various channels)

• Need to assess in appropriate context
  – exogenous (weather, airport/sector capacities, strikes, military)
  – robustness (schedule, flight scope, range checks, last-filed FPL)
  – reporting protocols (e.g. reactionary (‘knock-on’) delay)

• Sampling frameworks (Europe c.f. US), carriers:
  – in US required report performance data if ≥ 1% total domestic scheduled service passenger revenues (+ some report voluntarily)
  – in EU operating > 35 000 flights per year within EU airspace
  – in 2014: US = 16, EU = 100; both IFR ≈ 70%
## New metrics & sampling insights

<table>
<thead>
<tr>
<th>Data level by region</th>
<th>Europe</th>
<th>US</th>
<th>China</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lower delineation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(no aircraft types or delay data)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of airports</td>
<td>497</td>
<td>595</td>
<td>185</td>
</tr>
<tr>
<td>No. of airlines</td>
<td>153</td>
<td>81</td>
<td>17</td>
</tr>
<tr>
<td><strong>Higher delineation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(with aircraft types and delay data)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of airports</td>
<td>1854</td>
<td>286</td>
<td>–</td>
</tr>
<tr>
<td>No. of airlines</td>
<td>100</td>
<td>16</td>
<td>–</td>
</tr>
</tbody>
</table>

* Open source repository, flights and airport data, worldwide coverage. Flights for June 2015.
† EUROCONTROL; all intra-European IFR flights, March through December, 2011.
New metrics & sampling insights

• Complexity science: networks (CNT)
  – multiple components; uncertainty
  – non-linear dynamics: emergent behaviour
  – non-analytical models, e.g. ABM
  – metrics & methods (community detection)

• ComplexWorld network
  – SESAR ER (NEXTOR)

• Some simple metrics
  – link density: active links in the network / all possible links
  – maximum degree: degree of the most connected node
  – assortativity (degree correlation): correlation coefficient between the degrees of pairs of nodes connected by a link
  – -1 => all nodes connected to nodes of different degree
New metrics & sampling insights

(OpenFlights data)
New metrics & sampling insights

(OpenFlights data)
New metrics & sampling insights

(ALL-FT+ & RITA data)
New metrics & sampling insights

(ALL-FT+ & RITA data)
New metrics & sampling insights

• Literature demonstrates many sampling constraints
  – *purposive*, e.g. most connected airports / region of airspace
  – limited to data from (a) given airline(s) (or alliance)
  – data quality/availability for smaller airports / smaller airlines/LCCs
  – data purchase cost
  – computational cost (including data cleaning; 14%)

• Larger airports and airlines are often over-represented

• Non-saturation => often no obvious sampling threshold by which nodes may be safely discarded

• Top 34 airports (Europe & US) => ≈2% error
  – caution thus advised regarding changes of this order
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## Multiple targets

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<tr>
<th></th>
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<th>US</th>
<th>China</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Programme</strong></td>
<td>SESAR</td>
<td>NextGen</td>
<td>ATMB Strategic Development Programme</td>
</tr>
<tr>
<td><strong>Target year</strong></td>
<td>2035</td>
<td>2025*</td>
<td>2030</td>
</tr>
<tr>
<td><strong>Baseline year (for relative changes)</strong></td>
<td>2005</td>
<td>2009</td>
<td>2015</td>
</tr>
</tbody>
</table>

(ICA0 KPAs (11))

<table>
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<th>China</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Safety</strong></td>
<td>Improve safety 10-fold</td>
<td>Comm. carrier fatalities ≤ 6.2 per 100 million pax</td>
<td>Reduce ATC-attributable accident rate by 20% by flight volume</td>
</tr>
<tr>
<td><strong>Capacity</strong></td>
<td>Increase capacity 3-fold</td>
<td>12% increase, core airports</td>
<td>Increase capacity 3-fold</td>
</tr>
<tr>
<td><strong>Efficiency</strong></td>
<td>Reduce avg dly by 1-3 min†</td>
<td>Reduce delays by 27%</td>
<td>Average ATC-attributable delay &lt; 5 mins</td>
</tr>
<tr>
<td><strong>Environment</strong></td>
<td>10% reduction in impact of flights on environment</td>
<td>Reduce fuel burned per km by ≥ 2% annually</td>
<td>Reduce CO₂ by 10% (kg/km)</td>
</tr>
</tbody>
</table>

* Selected targets shown relate to intermediate target year 2018. Delay reduction allocated to efficiency KPA for ease of comparison.
† Declared within SES Performance Scheme within capacity KPA; target relative to 2012.
¶ Corresponding target set within SES Performance Scheme for 2015-2019.
Multiple targets

- Passenger context: ultimate customer
  - Advisory Council for Aeronautics Research in Europe; and White Paper (both 2011)
  - “highly ambitious goals” (x5)
  - “90% of travellers within Europe are able to complete their journey, door-to-door within 4 hours.”
  - ‘Destination 2025’ (FAA, 2011) – qualitative

- Pax delay > flight delay
  - often dominates delay costs & behaviour
  - 1.6 – 1.7 (US); 1.3 – 1.9 (Europe)
  - flight-centric assessment only (x3)
  - how measure progress?
Multiple targets

KPIs established for 2015
(all in Single European Sky Performance Scheme, RP2)
Multiple targets

- 2015 (start of SES RP2; Master Plan Edition 3)
- 2020 (SES targets; start of RP3)
- 2036+ (doubling of 2005 traffic)
- 2050 (Flightpath 2050 vision)

- Business forces
- Regulatory forces
Challenges & opportunities
Challenges & opportunities

• Metrics – methods
  – more focus: costs (cancellation), propagation, predictability
  – often cannot see differences in flight-centric metrics only
  – US analyses more advanced; several pax-centric metrics proposed
  – complementarity: complexity & classical – metrics & methods

• Metrics – trade-offs
  – ‘basic’ (e.g. flexibility and predictability)
  – monetised v. non-monetised (resilience)
  – regulatory v. market forces
  – KPAs, stakeholders: horizontal & vertical
  – local v. network (resilience engineering: polycentric governance best)
  – capture of non-linearity effects in models
Challenges & opportunities

• Data
  – how much of a network is ‘enough’?
  – more work ahead on sampling protocols; clearly need smaller airports
  – focus on particular airlines or routes is fine, but not a network proxy
  – accessibility: still a challenge in Europe
  – performance assessment advances: mandate- and data-driven
  – big data: diversity / open architectures, integrity – dynamic metrics?

• Standardisation and collaboration
  – EU-US harmonised KPI reporting, in coordination with ICAO
  – collaborations between China and US, China and EUROCONTROL
  – ATFM delay established as a proven leading indicator

• Performance assessment harmonisation across regions
  – account for different operational /market / regulatory contexts
  – balance between standardisation and adaptability
  – mutual international learning and research
Thank you

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