New perspectives for air transport performance

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Overview

• Background and objectives
• Flight prioritisation
• POEM – a new simulation tool
  – passengers and costs
  – key model features
• Scenarios and selected results
• Where next?
Background and objectives
Background and objectives

• To build a European network simulation model for flights and **explicit** passengers, which:
  - realistically captures airline decision-making and **costs**
  - includes a range of new performance metrics we have designed:
    - e.g. passenger-centric and propagation-centric
  - operates under a range of flight and pax prioritisation scenarios

• Key objectives, to investigate under these scenarios:
  - performance (cost and delay) trade-offs
  - propagation of delay through network

• Project was design and data front-loaded
• Included stakeholder workshops & two (airline) case studies
Flight prioritisation
Flight prioritisation

- **SESAR ConOps**
  - Step 1: time-based  2014-2025  CTAs
  - Step 2: trajectory-based  ~ 2025++  full 4D, CTOs
  - Step 3: performance-based  ~ 2025++  full free-routes

- **User Driven Prioritisation Process: a key component**
  - AOs request priority order for flights with restrictions
  - previously, only after Demand and Capacity Balancing had failed
  - ConOps 1 extends this scope to all normal situations, all phases
  - greatest applicability during capacity restrictions
  - early emphasis on pre-departure
  - consensus-seeking, AO iterations; else Network Arbitration function
POEM – a new simulation tool
- passengers and costs
Passengers and costs

• Policy-driven motivation
  – ultimate performance delivery to the passenger
  – Commission's new roadmap (2011) to a Single European Transport Area for 2050: pax mobility & network resilience
  – extension of passenger rights (e.g. review of Regulation 261)
  – ACARE Strategic Research & Innovation Agenda (Sep. 2012)

• Operational drivers
  – pax dominate most AO delay costs and therefore strongly influence AO behaviour in the network (strategically and tactically)
  – currently only using flight-centric metrics (Europe & US), although flight delay ≠ pax delay (US factors of 1.6 – 1.7)

• How can we measure specific progress without metrics?
## Passengers and costs

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>fleet</td>
<td>all fleet costs (depreciation, rentals &amp; leases)</td>
</tr>
<tr>
<td>fuel</td>
<td>Lido/Flight, BADA, manufacturers</td>
</tr>
<tr>
<td>crew</td>
<td>schemes, flight hours, on-costs, overtime</td>
</tr>
<tr>
<td>maintenance</td>
<td>extra wear &amp; tear powerplants/airframe</td>
</tr>
<tr>
<td>passenger</td>
<td>‘hard’ &amp; ‘soft’ (not internalised costs)</td>
</tr>
</tbody>
</table>

- well-established non-linearity ...
Passengers and costs

Graph showing primary cost (k€) against delay (mins) for different aircraft types.
POEM – a new simulation tool
- key model features
Key model features

- Evaluates different flight and pax prioritisation strategies
- Includes tactical costs to the airline (4 AO types)
- Key data-related characteristics
  - currently running 17SEP10 (busy day & month; 2010 c.f. 2012)
  - non-exceptional in terms of delays, strikes, weather
  - busiest 199 ECAC airports (cover 97% pax & 93% traffic for 2010)
  - 50 non-ECAC airports (based on pax flows in/out Europe)
  - extensive range and logic checks (e.g. speeds, registration seqs)
  - taxi-out unreliable; taxi-in missing; IOBT c.f. schedule
  - calibration (ind. sources, e.g. network delays (13.9±0.1) and LFs)
- Unique combination of PaxIS and PRISME data ...
Key model features

- aggregated PaxIS (IATA ticket) pax data allocated onto individual flights (PRISME traffic data, from EUROCONTROL)
- assignment algorithms respecting aircraft seat configurations and load factor targets
- full pax itineraries built respecting MCTs and published schedules
- 30 000 flights
- 2.5 million pax
- 150 000 routings
Key model features

- Gate-to-gate aircraft rules, and pax connection rules
- Varying levels of fidelity, for example:
  - Rule 23: en-route (some recovery, 5 min residual, wind; later ...)
  - Rule 33: passenger reaccommodation
    - Regulation (EC) 261/2004; IATA (involuntary rerouting & proration rules)
    - trigger: pax late at gate (a/c not wait); cancellation; (denied boarding)
    - aircraft seat configuration data used with routing sub-rules
    - passenger prioritisation sub-rules (alliances, ticket flexibility, ties)
    - hard costs (rebooking, cost of care, overnight accommodation)
    - soft costs (dissatisfaction, market share; capped at 5 hours)
    - (passenger value of time)
    - multiple sources, including airline input and airline review
Key model features

- event-driven: event stack, ordered sequence of events, each with a stamp
- dynamic tracking of costs for each a/c & passenger
- some pre-computed cost functions: recursive (from end of day backwards along propagation tree); discrete (dly: 0, 5, 10, ...)
- single-processor: 25-50 minutes to run one day
- cloud-computing platform: approximately 2 minutes
- stable after appx. 10 runs
Key model features

[...] (17-Sep-2010 12:25:00) 47 out of 49 of pax (95.92 pct.) of DLH_EDDLEGBB02:15877 were ready, flight over 80 pct. occupancy, no more delay added

(17-Sep-2010 12:25:00) Total cost of flight DLH_EDDLEGBB02:15877 departing at 17-Sep-2010 12:25:00 now estimated at 127.15 euros

(17-Sep-2010 12:25:00) No further pax delay will be introduced, thus flight DLH_EDDLEGBB02:15877 is now pushback ready, reaccommodating connecting pax

(17-Sep-2010 12:25:00) Pax group DLH1815:37550 of 2 inflex pax coming from DLH_EDDHEDDL06:12246 to EGBB did not make it to DLH_EDDLEGBB02:15877 (no more connections afterwards) and need to be reaccommodated

(17-Sep-2010 12:25:00) 2 inflex pax of group DLH1815:37550 of DLH_EDDHEDDL06:12246 that missed DLH_EDDLEGBB02:15877 were successfully reaccommodated in DLH_EDDLEGBB03:23396 same alliance, DLH1815/1:145607 Arrival: 17-Sep-2010 17:50:00 delay: 04:00'00" (airport wait 03:01'51"

(17-Sep-2010 12:25:00) Trying to reaccommodate the 80 pax waiting at EDDL:10 (DUS)

(17-Sep-2010 12:25:00) A total of 2 pax of DLH_EDDLEGBB02:15877 were left behind and all of them were successfully reaccommodated

(17-Sep-2010 12:25:00) Flight SAS_ENKBENGM03:15843 loading 67 pax and all of the 67 pax are not coming from a previous flight. There are NO connecting pax

(17-Sep-2010 12:25:00) There are 29 pax groups in SAS_ENKBENGM03:15843 connecting with another flight afterwards (SAS3310:87574, SAS3311:87575, SAS3312:87576, SAS3313:87577, SAS3314, [...]

(KSU-OSL)
Scenarios and selected results
## Scenarios and selected results

<table>
<thead>
<tr>
<th>Type, and level</th>
<th>Designator</th>
<th>Summary description</th>
</tr>
</thead>
<tbody>
<tr>
<td>No-scenario, 0</td>
<td>S₀</td>
<td>No-scenario baselines (reproduces historical operations for baseline traffic day)</td>
</tr>
<tr>
<td>ANSP, 1</td>
<td>N₁</td>
<td>Prioritisation of inbound flights based on simple passenger numbers</td>
</tr>
<tr>
<td>ANSP, 2</td>
<td>N₂</td>
<td>Inbound flights arriving more than 15 minutes late are prioritised based on the number of onward flights delayed by inbound connecting passengers</td>
</tr>
<tr>
<td>AO, 1</td>
<td>A₁</td>
<td>Wait times and associated departure slots are estimated on a cost minimisation basis, with longer wait times potentially forced during periods of heavy ATFM delay</td>
</tr>
<tr>
<td>AO, 2</td>
<td>A₂</td>
<td>Departure times and arrival sequences based on delay costs – A₁ is implemented and flights are independently arrival-managed based on delay cost</td>
</tr>
<tr>
<td>Policy, 1</td>
<td>P₁</td>
<td>Passengers are reaccommodated based on prioritisation by final arrival delay, instead of by ticket type, but preserving interlining hierarchies</td>
</tr>
<tr>
<td>Policy, 2</td>
<td>P₂</td>
<td>Passengers are reaccommodated based on prioritisation by final arrival delay, regardless of ticket type, and also relaxing all interlining hierarchies</td>
</tr>
</tbody>
</table>
flight-centric
new metrics

N₁ & N₂  P₁  P₂  A₁

scenarios

?
<table>
<thead>
<tr>
<th>Core metric</th>
<th>Units</th>
<th>N₁ &amp; N₂</th>
<th>P₁</th>
<th>P₂</th>
<th>A₁</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flight departure delay</td>
<td>mins / flight</td>
<td>Inbound prioritisation based on simple pax numbers, or on onward flights delayed</td>
<td>Passenger reaccommodated based on delay at final destination (preserving interlining hierarchies)</td>
<td>Relaxing interlining hierarchies</td>
<td>Departures times based on cost minimisation (&amp; consideration of ATFM delay)</td>
</tr>
<tr>
<td>Flight arrival delay</td>
<td>mins / flight</td>
<td></td>
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<tr>
<td>Departure delay of departure-delayed flights</td>
<td>mins / flight</td>
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<tr>
<td>Arrival delay of arrival-delayed flights</td>
<td>mins / flight</td>
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<tr>
<td>Pax departure delay</td>
<td>mins / pax</td>
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<td>Pax arrival delay</td>
<td>mins / pax</td>
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<td>mins / pax</td>
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<tr>
<td>Passenger value of time</td>
<td>Euros / pax</td>
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<tr>
<td>Non-passerenger costs</td>
<td>Euros / flight</td>
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<tr>
<td>Per-flight pax hard cost</td>
<td>Euros / flight</td>
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<tr>
<td>Per-flight pax soft cost</td>
<td>Euros / flight</td>
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<tr>
<td>Total flight cost</td>
<td>Euros / flight</td>
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<tr>
<td>Total flight cost per minute of departure delay</td>
<td>Euros / min</td>
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<tr>
<td>Reactionary delay ratio</td>
<td>ratio</td>
<td></td>
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**Flight-centric vs. New Metrics**

No significant changes in current flight-centric metrics: stresses need for passenger-centric metrics.
Scenarios and selected results

- $A_1$ and reactionary delay
  - increases from 49% ($S_0$) to 51% as a proportion of all dep. delay
  - ... but focused on relatively few (waiting) aircraft (purposefully)
  - ... saving in total costs wholly due to reduction in hard costs
  - explicit estimations of reactionary delay: a significant advance

- Smaller airports implicated in delay propagation
  - more than hitherto commonly recognised
  - expedited turnaround; spare crew (& a/c); connectivity & capacity

- Back-propagation important in persistence of network delay
  - CDG, MAD, FRA, LHR, ZRH, MUC: all $>100$ hours (baseline day)
  - most delay distributed between a relatively limited no. of airports

- Granger causality in complex network theory context ...
Flight delay causality network for $S_0$

redder => higher connectedness; larger => more nodes ‘forced’
Flight delay causality network for $A_1$
Scenarios and selected results

• Main conclusions of Granger causality analyses
  – comparing eigenvector centrality rankings through Spearman rank correlation coefficients: all four layers almost completely different
  – i.e. airports play different roles in terms of flight and passenger delay propagation, and different again under $A_1$

• Main effects of $A_1$
  – delay propagation contained within smaller airport communities
  – ... but these communities more susceptible to such propagation
  – largest persistent airports: Athens, Barcelona & Istanbul Atatürk
  – similar findings earlier vulnerability analysis & by Fleurquin et al. (2013)
Scenarios and selected results

\[ M_{a,t}^d = \begin{pmatrix} d_{1,1} & d_{2,1} \\ d_{1,2} & d_{2,2} \\ \vdots & \vdots \end{pmatrix} \]
Where next?
Where next?

- **Model enhancements**
  - en-route: more sophisticated delay recovery rules (4DT; DCI)
  - higher fidelity ATFM modelling
  - cost recoveries (e.g. crew hours; cancelled flights)

- **Schedule robustness**
  - +1 minute of delay (avg: 14.9); +1% cancellations (morning); ...
  - greater disruption: more localised or more severe & widespread

- **Adaptive features, ability to investigate:**
  - other metrics (e.g. RP2(/3) delay targets) & rules (e.g. UDPP)
  - future traffic levels, aircraft sizes, LFs, frequencies & wave structures
  - new AO policies / EU regulation impacts (re. pax and emissions)
  - performance of particular airlines or routes (c.f. network)

- **Integration with other tools (tactical and strategic)**
Thank you