Performance Evaluation of Individual Aircraft Based Advisory Concept for Surface Management

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Agenda

• Introduction: Surface management, departure metering and NASA surface management tool
• 2012 experiments to test NASA system
• Experiment results
• Next steps
Dallas Airport

- Currently, aircraft delayed in runway queue
- Excess taxi-out times, fuel consumption and emissions
- Departure metering: limiting aircraft near runway and taxiways
Potential Benefits of Airport Departure Metering

• Two recent FAA sponsored studies:
  – At 8 major US airports, cumulative fuel savings of $2.3 billion USD from 2010 to 2030\textsuperscript{1}
  – Using FY2011 traffic data, benefits at 43 top US airports can range from\textsuperscript{2}:
    • 52,000 to 372,000 taxi hours reduction
    • $42 million to $300 million USD fuel reduction in FY2012 dollars

\textsuperscript{1} An Approach for Estimating Current and Future Benefits of Airport Surface Congestion Management Techniques. Alex Nakahara, Tom Reynolds. 12th AIAA ATIO Conference, 2012
Departure Metering

• In US
  – N-control
  – Collaborative Departure Queue Management (CDQM)
  – JFK airport metering system

• In Europe
  – Eurocontrol and DLR Departure MANager (DMAN)
  – Integration with Surface MANager (SMAN)

• NASA’s Spot And Runway Departure Advisor (SARDA)
  – In 2010, metering at spot
SARDA Concept

• Collaborative metering at gate through SARDA
  – Tactical gate hold (hold after push-back readiness)
  – Strategic gate hold (hold 30 mins or more in advance)

• Provide either Target Movement Area Time (TMAT) and push-back time

• Tactical tower advisories in both cases
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Spot And Runway Departure Advisor (SARDA) - Concept

- **Goal**: A collaborative decision support tool for airlines and tower controllers to enhance the efficiency of surface traffic

- Airline Operator Advisory – Surface Collaborative Decision Making (CDM)
  - Provide gate push-back times to airlines

- Ground Controller Advisory
  - Provide spot/ramp release schedule to reduce taxi delay while maintaining maximum runway throughput

- Local Controller Advisory
  - Provide take-off and crossing sequence for maximum runway usage while addressing all criteria
SARDA Scheduler

• **Stage 1: Runway Scheduler**
  – Estimates of earliest time available at runway are inputs
  – Wake vortex separation (3 weight classes)
  – RNAV routes
  – Separation requirements for runway crossings
  – TMI constraints

• **Stage 2: Spot/Gate time calculation**
  – Spot time (and gate time): Subtract estimated taxi-time from stage 1 calculated runway times

• Plan for next 15 minutes, update plan every 10 seconds
SARDA Scheduler

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Plan for next 15 minutes, update plan every 10 seconds

30th percentile of unimpeded speed was chosen for both stages for 2012 experiments
Initial solution obtained through Dynamic Program

For recalculation, previous solution is used as a candidate solution

Local search heuristic (combination of insertion heuristic and neighborhood search) provides a local optimal solution (<10 second always)

Freeze horizon: to reduce “jumps” in advisory
SARDA Development

• 2010 human-in-the-loop (HITL) simulations - hold at spot
• 2012 HITL simulations: additions
  – Traffic management initiatives (TMI)
  – Out-the-window view
  – Gate holding (instead of spot holding)
  – Uncertainty in aircraft taxi speed
  – Electronic Flight Strips (EFS)
  – Single scheduler
Simulation Details

• Tactical gate hold
  – Aircraft assumed push-back ready at scheduled push-back time
  – Actual push-back times calculated from SARDA spot release time
  – No negotiation (on changes in SARDA times)
  – Airlines meet SARDA gate push back time

• Ground and local controller advisory – through EFS

• Run traffic with SARDA advisories, and without SARDA (aka “Baseline”)

• Traffic Management Initiatives (TMI) in all runs
Simulation Details

- East side DFW (17R departures and 17C arrivals)
- No perimeter taxiway
- 3 weeks, 6 controllers (2 controllers per week)
- 2 traffic levels - medium and heavy, 2 scenarios each
  - Medium 1, Medium 2, Heavy 3 and Heavy 4
  - 16 runs per week, 48 total
  - 6 runs for each scenario for advisory and baseline (with different controllers)
- 5 Pseudo-pilots
Simulation Caveats

• “Advisories” had to be followed
• Ramp area
  – Gate management not implemented
  – De-conflicted ramp movement under development
Some Pictures
Agenda

• Introduction: Airport departure metering and SARDA
• 2012 SARDA experiments
• Experiment results
• Next steps
Runway Usage Comparison

- Cumulative runway usage, calculated every 5 minutes
- Expectation: No reduction in runway usage with advisory
Runway Usage Comparison

Cumulative runway usage - Medium 1

Number of departure take-offs and arrival crossings up to a particular time
Runway Usage Comparison

Number of departure take-offs and arrival crossings up to a particular time
Runway Usage Comparison

Number of departure take-offs and arrival crossings up to a particular time

**Cumulative runway usage - Medium 1**

- Advisory
- Baseline

**Cumulative runway usage - Medium 2**

- Advisory
- Baseline

**Cumulative runway usage - Heavy 3**

- Advisory
- Baseline

**Cumulative runway usage - Heavy 4**

- Advisory
- Baseline
Runway Usage Comparison

No observable change in runway usage with SARDA advisory

Number of departure take-offs and arrival crossings up to a particular time
Departure Taxiing Delay

• Delay definition
  – Observed time minus unimpeded time
  – Unimpeded taxi time: Time to travel on that route (gate-spot-queue combination) at 17 knots without stops

• Taxiing delay for departures: Delay in ramp, taxiways, queues and runway
Taxiing Delay for Departures
(ramp, taxiway, queue)

3 min reduction in medium (45%)
5.5 min reduction in heavy (60%)
### Taxiing Delay for Departures (ramp, taxiway, queue)

- Observed reduction in taxiing delay statistically significant
- Reduction in mean as well as variance

![Box plot of taxiing delay for departures](image)

- **Max**
- **90th percentile**
- **75th percentile**
- **Mean**
- **Median**
- **25th percentile**
- **10th percentile**
- **Min**

### Taxiing delay for departures

<table>
<thead>
<tr>
<th>Test condition</th>
<th>Delay (min)</th>
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<tbody>
<tr>
<td>Adv 1</td>
<td>10</td>
</tr>
<tr>
<td>Base 1</td>
<td>15</td>
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<td>Adv 3</td>
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<tr>
<td>Base 3</td>
<td>10</td>
</tr>
<tr>
<td>Adv 4</td>
<td>5</td>
</tr>
<tr>
<td>Base 4</td>
<td>10</td>
</tr>
</tbody>
</table>
Overall Delay

Compared to baseline, advisory resulted in statistically significant reduction in scheduled delay ($p \sim 0.02$)
Traffic Management Initiatives (TMI)

- Each TMI aircraft has a scheduled take-off time (displayed in Electronic Flight Strips)
- Aircraft should take off within 1 minute before or 1 minute after this time
- If cannot be done, release as close to time as possible (no new TMI time issued)
TMI Compliance and Effects

No evidence of compliance being affected by advisory

Outlier: Controller sent aircraft to wrong runway queue
Observation: TMI aircraft have higher taxiing delay than non-TMI aircraft, and advisory reduces this effect (statistically significant)
- Observed reduction in fuel consumption
  - 23% average in medium
  - 33% average in heavy
- In advisory runs, fuel consumption seems less sensitive to traffic level
No observed change in arrival aircraft delay
Other Results

• Controller workload
  – Various surveys (post-run and post-study) conducted and real time workload measurements taken
  – No observable increase in workload with use of advisory
  – Further details in “Usability Evaluation of the Spot and Runway Departure Advisor (SARDA) Concept in a Dallas/Fort Worth Airport Tower Simulation” by Miwa Hayashi

• Reduction in taxiing delay variation suggests increased predictability; ongoing work on measuring predictability
Summary

• 2012 SARDA HITL simulations
  – Tactical gate hold with tactical tower advisories
  – Similar runway utilization as in baseline
  – Similar TMI compliance as in baseline
  – Reduction in taxiing delay for departures (45% in medium, 60% in heavy), and reduced variation
  – Reduction in fuel consumption for departures (23% in medium, 33% in heavy)
  – Reduction in overall delay was observed across 48 runs
Next Steps

• Analysis at another airport
  – Challenges: ramp movement, surveillance, different runway layout and more
  – Collaboration with US Airways for SARDA at Charlotte airport

• SARDA usage in off-nominal cases

• Strategic gate hold through SARDA
A word of thanks....