SARDA HITL Simulations: System Performance Results

Gautam Gupta
Agenda

• SARDA concept introduction
• HITL description
• System performance results
Motivation and Concept

• Motivation
  – Currently, departure delay at runway queues
  – Leads to inefficient fuel consumption and higher emissions (at queues and taxiway)

• Operational Concept
  – Hold aircraft back at gates/holding areas in collaboration with airlines
  – Provide “advisories” to Ground and Local Controllers, incorporating future traffic (through airline collaboration)
  – Increased efficiency and predictability in surface operations
  – Reduced fuel consumption and emissions
  – No concession in runway throughput
Spot And Runway Departure Advisor (SARDA)

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

- **Airline Operator Advisory – Surface CDM**
  - Aim: Provide gate push-back times to airlines

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

- **Local Controller Advisory**
  - Aim: Provide take-off and crossing sequence for maximum runway usage while addressing all criteria
Current Operations
Improvements over SARDA 2010

• Traffic management initiatives (TMI)
• Out of the window view
• Gate holding (instead of spot holding)
• Uncertainty in aircraft taxi speed (12 to 17 knots)
• Electronic Flight Strips (EFS)
• Single scheduler
Simulation Details (1)

• Surface Collaborative Decision Making (CDM)
  – Gate push-back readiness communicated by airline
  – Actual gate push-back times based on SARDA spot release
  – Idealized
    • Airline inputs accurate
    • No re-negotiation
    • Airlines meet SARDA gate push back
Simulation Details (1)

• Surface Collaborative Decision Making (CDM)
  – Gate push-back time readiness communicated by airline
  – Actual gate push-back times based on SARDA spot release
  – Idealized
• Ground and local controller advisory – through EFS
• Run traffic with SARDA advisories, and without SARDA (aka “Baseline”)
• Traffic Management Initiatives (TMI) in all runs
• Full out-of-the-window tower simulation
Simulation Details (2)

- 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
  - M1, M2, H3 and H4
  - 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
Data Collected

- SMS data
  - Positioning
  - Scheduler inputs and outputs
- Electronic flight strip logs
- Voice recordings
- Video recordings
- Workload (Workload Assessment Keypad)
- Predictability
- Surveys
Data Collected

- SMS data
  - Positioning
    - Scheduler inputs and outputs
- Electronic flight strip logs
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Agenda

• SARDA concept introduction
• HITL description
• System performance results
• Did SARDA reduce taxiing aircraft through gate holding?

• Was there any loss in runway usage due to holding?

• What are the benefits?
Gate Holding Effect

• Aircraft “waiting” in the system:
  At every 1 minute, number of departure aircraft that
  – Have pushed back and
  – Have not taken off within unimpeded taxi time

• Expectation: lower for advisory
Gate Holding Effect

At every 1 minute, number of departure aircraft that have pushed back but not have not taken off within unimpeded time
Gate Holding Effect

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Gate Holding Effect

At every 1 minute, number of departure aircraft that have pushed back but not taken off within unimpeded time
Gate Holding Effect

At every 1 minute, number of departure aircraft that have pushed back but not taken off within unimpeded time observed no more than 6 aircraft "waiting" on the surface with advisory.
Did SARDA reduce taxiing aircraft through gate holding?

- Was there any loss in runway usage due to holding?
- What are the benefits?
Runway Usage Comparison

• Cumulative runway usage
  – Number of departure take-offs and arrival crossings till a particular time
  – Calculated every 5 minutes

• Expectation: No reduction in runway usage with advisory
Runway Usage Comparison

Cumulative runway usage - scenario m1

Aircraft count

Simulation time (minutes)

0 5 10 15 20 25 30 35 40 45 50 55

Advisory mean
Baseline mean

Advisory
Baseline

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

Cumulative runway usage - scenario m1

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

Cumulative runway usage - scenario m1

Cumulative runway usage - scenario m2

Cumulative runway usage - scenario h3

Cumulative runway usage - scenario h4

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

Cumulative runway usage - scenario m1

Cumulative runway usage - scenario m2

No observable change in runway usage with SARDA advisory

Number of departure take-offs and arrival crossings till a particular time
Did SARDA reduce taxiing aircraft through gate holding?

Was there any loss in runway usage due to holding?

What are the benefits?

- Taxiing delay reduction
- Potential fuel savings
Delay

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

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

Mean over all aircraft for that scenario:
- 3 min reduction in medium (45%)
- 5.5 min reduction in heavy (60%)
Taxiing Delay for Departures (ramp, taxiway, queue)

Mean and percentile over all aircraft for that scenario
Taxi Delay - Distribution

Large variation in delay in baseline
Fuel Consumption

Extra fuel per aircraft

- 22% reduction in medium
- 34% reduction in heavy
Fuel Consumption

• 34% fuel savings = 70kg fuel per aircraft

• Daily operations: 6 peak periods of 50 aircraft each

• At $3/gallon, annual savings: 6 million USD
Did SARDA reduce taxiing aircraft through gate holding?

Was there any loss in runway usage due to holding?

What are the benefits?
- Taxiing delay reduction
- Potential fuel savings
- TMI (Traffic Management Initiatives)
**TMI**

- **Details**
  - 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)

- **Compliance?**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Baseline</th>
<th>Advisory</th>
</tr>
</thead>
<tbody>
<tr>
<td>m1</td>
<td>93%</td>
<td>100%</td>
</tr>
<tr>
<td>m2</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>h3</td>
<td>86%</td>
<td>100%</td>
</tr>
<tr>
<td>h4</td>
<td>93%</td>
<td>100%</td>
</tr>
</tbody>
</table>
No observed change in TMI compliance with SARDA but TMI delays similar to non-TMI aircraft.
Did SARDA reduce taxiing aircraft through gate holding?

Was there any loss in runway usage due to holding?

What are the benefits?
- Taxiing delay reduction
- Potential fuel savings
- TMI (Traffic Management Initiatives)
- Effect on arrivals
Arrival Delay

No observed effect on arrival aircraft
✅ Did SARDA reduce taxiing aircraft through gate holding?

✅ Was there any loss in runway usage due to holding?

**What are the benefits?**

- Taxiing delay reduction
- Potential fuel savings
- TMI (Traffic Management Initiatives)
- Effect on arrivals
- Uniform system performance
Uniform System Performance

• SARDA advisories seem to make system performance
  – Uniform across different traffic levels
Uniform System Performance

- SARDA advisories seem to make system performance uniform across different traffic levels.
Uniform System Performance

• SARDA advisories seem to make system performance
  – Uniform across different traffic levels
  – Uniform across different controllers
Uniform System Performance

- SARDA advisories seem to make system performance
  - Uniform across different traffic levels
  - Uniform across different controllers
Summary

• Observations from SARDA experiment
  – Reduced delays (60%)
  – Reduced fuel (34%)
  – No observed change in runway usage
  – Reduced variation in system performance

• Lastly......
Effect on Individual Aircraft

- SARDA gate holding: moves delay from runway to gate
  - Departure delay: Delay from scheduled wheels-off time
Effect on Individual Aircraft

- SARDA gate holding: moves delay from runway to gate
- Effect on individual aircraft take off time?
  - 6 runs per scenario in baseline and advisory
  - Std deviation of aircraft take off times over 6 points

![Graph showing std dev in aircraft take-off times (min)]
Effect on Individual Aircraft

- **Scenario m1**
  - Baseline
  - Advisory

- **Scenario h3**
  - Baseline
  - Advisory

- **Scenario m2**
  - Baseline
  - Advisory

- **Scenario h4**
  - Baseline
  - Advisory
Effect on Individual Aircraft

SARDA advisories reduce variation in individual aircraft take off times