SARDA HITL Simulations: System Performance Results

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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
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
- Voice recordings
- Video recordings
- Workload (Workload Assessment Keypad)
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- Surveys
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.
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Gate Holding Effect

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Gate Holding Effect

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

Observed no more than 6 aircraft “waiting” on the surface with advisory

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

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

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

Total delay, scenario - h3

Total delay (min)

Baseline

0% 10% 20% 30% 40% 50% 1 3 5 7 9 11 13 15 17 19 >20
Taxi Delay - Distribution

Large variation in delay in baseline
Fuel Consumption

### Extra fuel per aircraft

<table>
<thead>
<tr>
<th></th>
<th>Advisory</th>
<th>Baseline</th>
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<tbody>
<tr>
<td>Medium 1</td>
<td></td>
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<tr>
<td>Medium 2</td>
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<td></td>
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<tr>
<td>Heavy 3</td>
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<tr>
<td>Heavy 4</td>
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- **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)
• 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?

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<thead>
<tr>
<th>Scenario</th>
<th>Baseline</th>
<th>Advisory</th>
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<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>
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TMI

Taxi delay per aircraft

<table>
<thead>
<tr>
<th>Delay (minutes)</th>
<th>Medium 1</th>
<th>Medium 2</th>
<th>Heavy 3</th>
<th>Heavy 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advisory</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Baseline</td>
<td>8</td>
<td>8</td>
<td>8</td>
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</tr>
</tbody>
</table>

Taxi delay per aircraft - non TMI

- Medium 1: Advisory: 6, Baseline: 2
- Medium 2: Advisory: 7, Baseline: 4
- Heavy 3: Advisory: 12, Baseline: 10
- Heavy 4: Advisory: 6, Baseline: 14

Taxi delay per aircraft - TMI only

- Medium 1: Advisory: 2, Baseline: 4
- Medium 2: Advisory: 3, Baseline: 5
- Heavy 3: Advisory: 12, Baseline: 10
- Heavy 4: Advisory: 6, Baseline: 14
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
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
SARDA advisories seem to make system performance uniform across different traffic levels and 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

![Dep delay chart](chart.png)
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_deviation_of_aircraft_take_off_times]
Effect on Individual Aircraft

Scenario m1

Scenario h3

Scenario m2

Scenario h4
Effect on Individual Aircraft

SARDA advisories reduce variation in individual aircraft take off times