Modelling and Simulating Airport Surface Operations with Gate Conflicts

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SOSS is:

• A fast-time simulation environment for surface operations
• Used to develop and test surface scheduling concepts
• Currently testing a surface scheduling concept for Charlotte Douglas International (CLT)
Complex runway constraints

CLT Surface Operations Challenges
Complex runway constraints

Limited space for taxiing
CLT Surface Operations Challenges

Complex runway constraints
Limited space for taxiing
Heavy use of limited gates
Flights need the same gate at the same time:
- Arrival is early
- Departure is late or held for metering

Common in hub operations arrival/departure banks

Resolution option: Temporary parking in hardstands
Objectives

- Describe SOSS and new functionality to model hardstand operations
- Compare gate conflict management approaches’ impact on surface scheduling operations
Outline

• SOSS
• Gate Conflict Management
• Experiment Setup
• Results
SOSS Airport Model

Runways

Ramp

Gates

Active Movement Area (AMA)
SOSS Airport Model

- Departure Node
- Crossing Node
- Arrival Node
- Spot Node
- Dep Queue Node
Flight Taxi Movement and Routing
Scheduler Interface

Flight states and intent

Scheduler

Reroutes

Release times
- Gate nodes
- Hardstand nodes
Outline

• SOSS
• Gate Conflict Management
  – Prediction
  – Resolution options
  – Management approaches
• Experiment Setup
• Results
Gate Conflict Prediction

Departure Node

Gate Node

- pushback ready time
- departure
- target gate release time
- target takeoff time
Gate Conflict Prediction

Arrival Node
- arrival
- landing time

Departure Node
- target takeoff time
- gate IN time

Gate Node
- departure
- pushback ready time
- gate time separation
- target gate release time
Gate Conflict Prediction

Arrival Node

landing time

Arrival Node

arrival

Target takeoff time

target
takeoff time

Gate Node

departure

Gate Node

departure

Earliest arrival gate IN < Target departure gate release + $\beta$

Predicted Gate Conflict

Pushback ready time

Gate IN time

gate IN time

Earliest arrival gate IN

Target gate release time

$\beta$
Gate Conflict Resolution

Resolution Options

- Departure Early Release
- Departure To Hardstand
- Arrival To Hardstand

Arrival Node (arrival)
- landing time

Departure Node (departure)
- target takeoff time
- gate IN time

Gate Node (departure)
- pushback ready time
- target gate release time

β
Gate Conflict Resolution

Arrival Node
- landing time
- arrival

Departure Node
- target takeoff time
- pushback ready time
- gate IN time

Gate Node
- departure

Departure Early Release

$\beta$
Gate Conflict Resolution

Arrival Node
- arrival
- landing time

Departure Node
- target
- takeoff time

Hardstand Node
- hardstand release time
- gate IN time

Gate Node
- pushback ready time
- departure

Time

\( \beta \)
Gate Conflict Prediction

Arrival Node

landing time

Arrival To Hardstand

Arrival To Hardstand

Departure Node

arrival

time

time

Hardstand Node

hardstand release time

takeoff time

Gate Node

departure

time

pushback ready time

time

target gate release time

$\beta$
## Gate Conflict Management Approaches

<table>
<thead>
<tr>
<th>Management Approach</th>
<th>Departure Early Release</th>
<th>Departure To Hardstand</th>
<th>Arrival To Hardstand</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Hardstand</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Departure Hardstand</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Arrival Hardstand</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Dual Hardstand</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Outline

• SOSS
• Gate Conflict Management
• **Experiment Setup**
• Results
Experiment Setup

**SOSS**
- 0.5 sec time step
- Surface congestion uncertainty modelled

**Demand Scenario**
- Departures (blue)
- Arrivals (red)

**Scheduler**
- Called every 10 seconds
- Surface metering ON
- Gate conflict management (4)
Outline

• SOSS
• Gate Conflict Management
• Experiment Setup

• Results
  – Resolution types
  – Gate time separation
  – Runway time predictability
  – Surface transit time
Results: Resolution Types

No Hardstand

Number of gate conflict flight pairs

None

Departure Early Release
Results: Gate Time Separation

- separation violation
- excess separation

Arrival and Departure To Hardstand

Dual Hardstand

Arrival Hardstand

Departure Hardstand

None

No Hardstand

actual gate separation - $\beta$

Gate Time Separation Results:

- **Arrival To Hardstand**
  - Dual Hardstand: Violation
  - Arrival Hardstand: Violation
  - Departure Hardstand: Violation
  - None: Violation
  - No Hardstand: Violation

- **Departure To Hardstand**
  - Dual Hardstand: Violation
  - Arrival Hardstand: Violation
  - Departure Hardstand: Violation
  - None: Violation
  - No Hardstand: Violation

- **Departure Early Release**
  - Dual Hardstand: Violation
  - Arrival Hardstand: Violation
  - Departure Hardstand: Violation
  - None: Violation
  - No Hardstand: Violation
## Results: Gate Time Separation

<table>
<thead>
<tr>
<th>Actual Gate Separation - $\beta$</th>
<th>Arrival and Departure To Hardstand</th>
<th>Departure To Hardstand</th>
<th>Arrival To Hardstand</th>
<th>Dual Hardstand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Separation Violation</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Excess Separation</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Arrival resolutions achieve more desired gate time separation</td>
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<td></td>
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</tr>
</tbody>
</table>

-5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Runway Time Prediction Error at Ready Time

Error (min)

Average

Departures involved in gate conflict

Other departures

No HS

Dep HS

Arr HS

Dual HS

Results: Runway Time Predictability
Results: Runway Time Predictability

Runway Time Prediction Error at Ready Time

Error (min)
-3 -2 -1 0 1 2 3
early late

Average

Departures involved in gate conflict
Other departures

No HS Dep HS Arr HS Dual HS No HS Dep HS Arr HS Dual HS
Results: Runway Time Predictability

Runway Time Prediction Error at Ready Time

- Average
- Standard Deviation

<table>
<thead>
<tr>
<th>Error (min)</th>
<th>late</th>
<th>early</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
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<tr>
<td>0</td>
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<tr>
<td>-3</td>
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</tbody>
</table>

Arrival resolutions have least impact runway time predictability

Departures involved in gate conflict (13)
Other departures (186)
Results: Surface Transit Time

Departures
(time between ready and takeoff)

Average transit time (min)

Flights involved in gate conflict
Other flights

Little difference in surface transit times for others
Results: Surface Transit Time

Departures (time between ready and takeoff)

Arrivals (time between landing and gate)

Arrival resolution greatly impact arrival transit times

Flights involved in gate conflict

Other flights

Average transit time (min)
### Summary and Conclusions

<p>| | |</p>
<table>
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<tbody>
<tr>
<td><strong>Gate Time Separation</strong></td>
<td>Arrival resolutions are best at achieving desired gate time separation</td>
</tr>
<tr>
<td><strong>Runway Time Predictability</strong></td>
<td>Arrival resolutions have least impact on runway time predictability</td>
</tr>
<tr>
<td><strong>Surface Transit Time</strong></td>
<td>Arrival resolutions greatly impact arrival surface transit times</td>
</tr>
</tbody>
</table>

- *Arrival Hardstand* approach is sufficient for simulations of tactical surface metering
- *Dual Hardstand* approach may be needed for simulations with large departure delays due to Traffic Management Initiatives
Future Work

• Explore use of *Dual Hardstand* approach in simulations with Traffic Management Initiatives
• Enhance SOSS to allow flights to be rerouted at any time
Questions

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