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)
CLT Surface Operations Challenges

Complex runway constraints
Complex runway constraints

Limited space for taxiing
CLT Surface Operations Challenges

Complex runway constraints

Limited space for taxiing

Heavy use of limited gates
Gate Conflicts

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

![Graph showing demand over time with peaks for arr (arrival) and dep (departure)]
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

- Dep Queue Node
- Departure Node
- Crossing Node
- Arrival Node
- Spot Node
SOSS Airport Model

- Departure Node
- Crossing Node
- Arrival Node
- Spot Node
- Dep Queue Node
- Hardstand Nodes
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
- landing time
- arrival

Departure Node
- target takeoff time

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

Arrival Node

landing time

predicted gate conflict

Earliest arrival gate IN < Target departure gate release + β

departure

target takeoff time

Gate Node

departure

target gate release time

Deperture Node

arrival

pushback ready time

gate IN time

time

β
Gate Conflict Resolution

Resolution Options

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

Arrival Node
- landing time

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

Gate Node
- departure
- target gate release time

\( \beta \)
Gate Conflict Resolution

Arrival Node

landing time

Departure Node

pushback ready time

gate IN time

target takeoff time

Gate Node

departure

Departure Early Release

\[ \beta \]
Gate Conflict Prediction

Arrival Node
- Arrival
- landing time

Departure Node
- Departure

Hardstand Node
- Pushback ready time

Gate Node
- Departure
- Target gate release time

Arrival To Hardstand
- Hardstand release time
- Target takeoff time
- Gate IN 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>
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</tr>
<tr>
<td>Departure Hardstand</td>
<td>✔</td>
<td>✔</td>
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<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

Ops per 15-min

0 10 20 30

0 30 60 90 120 150 180 210 240

Simulation time (minutes)

Scheduler
• Called every 10 seconds
• Surface metering ON
• Gate conflict management (4)
• SOSS
• Gate Conflict Management
• Experiment Setup
• Results
  – Resolution types
  – Gate time separation
  – Runway time predictability
  – Surface transit time
Results: Resolution Types

No Hardstand

None
Departure Early Release

Number of gate conflict flight pairs

0 1 2 3 4 5 6 7 8 9 10 11 12 13
### Results: Gate Time Separation

<table>
<thead>
<tr>
<th>Hardstand Type</th>
<th>Location</th>
<th>Separation Violation</th>
<th>Excess Separation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dual Hardstand</td>
<td>Arrival To Hardstand</td>
<td>X X X X X</td>
<td>X X X X</td>
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<tr>
<td></td>
<td>Departure To Hardstand</td>
<td>X X</td>
<td>X X X X</td>
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<tr>
<td>Arrival Hardstand</td>
<td>Arrival To Hardstand</td>
<td>X X X X</td>
<td>X X X X</td>
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<tr>
<td></td>
<td>Departure To Hardstand</td>
<td>X X</td>
<td>X X X X</td>
</tr>
<tr>
<td>Departure Hardstand</td>
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<td>None</td>
<td>None</td>
</tr>
<tr>
<td>No Hardstand</td>
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</tbody>
</table>

- **Arrival and Departure To Hardstand**
- **Separation Violation**: When the actual gate separation is less than the threshold, indicating a violation.
- **Excess Separation**: When the actual gate separation is greater than the threshold, indicating an excess.

**Actual Gate Separation - \( \beta \)**:

<table>
<thead>
<tr>
<th>Actual Separation</th>
<th>Hardstand Type</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>-5</td>
<td>Dual Hardstand</td>
<td>Arrival To Hardstand</td>
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<tr>
<td>-4</td>
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<tr>
<td>20</td>
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</tr>
</tbody>
</table>
Results: Gate Time Separation

Arrival and Departure To Hardstand

Dual Hardstand

Arrival To Hardstand

Arrival resolutions achieve more desired gate time separation

actual gate separation - $\beta$
Results: Runway Time Predictability

Runway Time Prediction Error at Ready Time

<table>
<thead>
<tr>
<th>Error (min)</th>
<th>Average</th>
<th>Departures involved in gate conflict</th>
<th>Other departures</th>
</tr>
</thead>
<tbody>
<tr>
<td>early</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>late</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Runway Time Prediction Error at Ready Time

- 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>
<th>late</th>
<th>early</th>
</tr>
</thead>
<tbody>
<tr>
<td>No HS</td>
<td>Dep HS</td>
<td>Arr HS</td>
<td>Dual HS</td>
<td>No HS</td>
</tr>
</tbody>
</table>

- **Departures involved in gate conflict**
- **Other departures**
Results: Runway Time Predictability

Runway Time Prediction Error at Ready Time

<table>
<thead>
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<th>Error (min)</th>
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<tr>
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<td></td>
</tr>
</tbody>
</table>

Arrival resolutions have least impact runway time predictability.
Results: Surface Transit Time

Departures
(time between ready and takeoff)

Average transit time (min)

<table>
<thead>
<tr>
<th></th>
<th>No HS</th>
<th>Dep HS</th>
<th>Arr HS</th>
<th>Dual HS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arrivals</td>
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<td>10</td>
<td>8</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Flights involved in gate conflict</td>
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<td>8</td>
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</tr>
<tr>
<td>Other flights</td>
<td>10</td>
<td>8</td>
<td>12</td>
<td>12</td>
</tr>
</tbody>
</table>

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

**Departures**
(time between ready and takeoff)

<table>
<thead>
<tr>
<th></th>
<th>No HS</th>
<th>Dep HS</th>
<th>Arr HS</th>
<th>Dual HS</th>
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</thead>
<tbody>
<tr>
<td>Average transit time (min)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

**Arrivals**
(time between landing and gate)

<table>
<thead>
<tr>
<th></th>
<th>No HS</th>
<th>Dep HS</th>
<th>Arr HS</th>
<th>Dual HS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average transit time (min)</td>
<td></td>
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</tbody>
</table>

- Arrival resolution greatly impact arrival transit times
- Flights involved in gate conflict
- Other flights
### Summary and Conclusions

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Gate Time Separation</td>
<td>Arrival resolutions are best at achieving desired gate time separation</td>
</tr>
<tr>
<td>Runway Time Predictability</td>
<td>Arrival resolutions have least impact on runway time predictability</td>
</tr>
<tr>
<td>Surface Transit Time</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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