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
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: dep (departure) and arr (arrival)
Objectives

- Describe SOSS and new functionality to model hardstand operations
- Compare gate conflict management approaches’ impact on surface scheduling operations
• SOSS
• Gate Conflict Management
• Experiment Setup
• Results
SOSS Airport Model

Runways

Ramp

Gates

Active Movement Area (AMA)
SOSS Airport Model

- Departure Node
- Arrival Node
- Crossing Node
- Spot Node
- Dep Queue 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

Arrival Node
- landing time
- arrival

Departure Node
- target takeoff time
- gate IN time

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

Arrival Node
- landing time

Departure Node
- target takeoff time

Gate Node
- pushback ready time
- target gate release time

**Predicted Gate Conflict**

\[
\text{Earliest arrival gate IN} < \text{Target departure gate release} + \beta
\]

- pushback ready time
- gate IN time
- target gate release time

\( \beta \) time
Gate Conflict Resolution

Resolution Options

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

Arrival Node

- arrival
- landing time

Departure Node

- target
- takeoff time

Gate Node

- departure
- pushback ready time

\[ \beta \]

time

gate IN time

target gate release time
Gate Conflict Resolution

Arrival Node
- arrival
- landing time

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

Gate Node
- departure
- pushback ready time

Departure Early Release

$\beta$
Gate Conflict Resolution

Arrival Node
- landing time
- arrival

Departure Node
- departure
- target takeoff time

Hardstand Node
- pushback ready time
- target hardstand release time

Gate Node
- departure
- gate IN time

\[ \beta \]
Gate Conflict Prediction

Arrival Node
- arrival
- landing time

Departure Node

Hardstand Node
- pushback ready time

Gate Node
- departure
- target gate release time

Target gate release time

Hardstand release time

takeoff time

gate IN time

time

arrival

landing time
## 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>
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<tr>
<td>Arrival Hardstand</td>
<td></td>
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<td>✔</td>
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<tr>
<td>Dual Hardstand</td>
<td>✔</td>
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</table>
Outline

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

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

**Demand Scenario**
- Arrivals
- Departures

**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
  - 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

- separation violation
- excess separation

Arrival and Departure To Hardstand

Dual Hardstand

Arrival Hardstand

Departure Hardstand

None

No Hardstand

Arrival To Hardstand

Departure To Hardstand

Departure Early Release

actual gate separation - $\beta$
Results: Gate Time Separation

- **Arrival and Departure To Hardstand**
- **Arrival To Hardstand**
- **Departure To Hardstand**

Arrival resolutions achieve more desired gate time separation
Results: Runway Time Predictability

Runway Time Prediction Error at Ready Time

<table>
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<tr>
<th>Error (min)</th>
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<th>Dep HS</th>
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<tr>
<td>early</td>
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Departures involved in gate conflict
Other departures
Results: Runway Time Predictability

Runway Time Prediction Error at Ready Time

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<tr>
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<th>Average</th>
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</tr>
<tr>
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<td></td>
</tr>
<tr>
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Departures involved in gate conflict
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Results: Runway Time Predictability

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Departures involved in gate conflict (13)
Other departures (186)

Arrival resolutions have least impact runway time predictability
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
### Summary and Conclusions

- **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.

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