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
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

Common in hub operations arrival/departure banks
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

- Arrival Node
  - landing time
  - arrival

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

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

Predicted Gate Conflict

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

Arrival Node
- Arrival
- Landing time

Departure Node
- Departure
- Target takeoff time

Gate Node
- Pushback ready time
- Time
- Target gate release time

$\beta$
Gate Conflict Resolution

Arrival Node

landing time

Departure Node

takeoff time

gate IN time

Gate Node

target gate release time

Resolution Options

• Departure Early Release
• Departure To Hardstand
• Arrival To Hardstand

arrival

departure

pushback ready time
Gate Conflict Resolution

Arrival Node

landing time

Departure Node
target takeoff time

gate IN time

Gate Node
departure

pushback ready time

Departure Early Release

arrival

β
Gate Conflict Resolution

Arrival Node
- landing time
- arrival

Departure Node
- departure
- target takeoff time
- hardstand release time
- gate IN time

Hardstand Node
- pushback ready time

Gate Node
- departure

$\beta$
Gate Conflict Prediction

Arrival Node

Departure Node

Hardstand Node

Gate Node

arrival

landing time

Arrival To Hardstand

hardstand release time

takeoff time

gate IN time

pushback ready time

departure

target gate release time

\[ \beta \]
<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><strong>No Hardstand</strong></td>
<td>✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Departure Hardstand</strong></td>
<td>✔</td>
<td>✔</td>
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<tr>
<td><strong>Arrival Hardstand</strong></td>
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<tr>
<td><strong>Dual Hardstand</strong></td>
<td>✔</td>
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</tr>
</tbody>
</table>
Outline

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

SOSS
0.5 sec time step

arrivals
departures

Surface congestion uncertainty modelled

Demand Scenario

Ops per 15-min

Simulation time (minutes)

0 30 60 90 120 150 180 210 240

departure
arrival

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

- Hardstand Arrival
- Hardstand Departure
- Dual Hardstand

separation violation excess separation

Arrival and Departure To Hardstand

Arrival To Hardstand

Departure To Hardstand

Departure Early Release

None

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

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

Runway Time Prediction Error at Ready Time

- **Average**

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

- Departures involved in gate conflict
- Other departures

- Early Departures
- Arrivals
- Dual HS

No HS

Dep HS

Arr HS

Dual HS
Results: Runway Time Predictability

Runway Time Prediction Error at Ready Time

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Standard Deviation</th>
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<tbody>
<tr>
<td>Late</td>
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<tr>
<td>No HS</td>
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<tr>
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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>
<tr>
<td>late</td>
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Arrival resolutions have least impact runway time predictability
Results: Surface Transit Time

<table>
<thead>
<tr>
<th>Flights involved in gate conflict</th>
<th>Other flights</th>
</tr>
</thead>
<tbody>
<tr>
<td>Departures (time between ready and takeoff)</td>
<td></td>
</tr>
</tbody>
</table>

- **No HS**
- **Dep HS**
- **Arr HS**
- **Dual HS**

**Average transit time (min)**

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

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

- No HS
- Dep HS
- Arr HS
- Dual HS

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

- No HS
- Dep HS
- Arr HS
- Dual HS

**Arrival resolution greatly impact arrival transit times**

**Flights involved in gate conflict**

**Other flights**
### Summary and Conclusions

<table>
<thead>
<tr>
<th>Gate Time Separation</th>
<th>Arrival resolutions are best at achieving desired gate time separation</th>
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<tbody>
<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>
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- *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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