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
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

Dep Queue Node

Departure Node

Crossing Node

Arrival Node

Spot 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

time

target takeoff time

pushback ready time

departure

target gate release time
Gate Conflict Prediction

Arrival Node
- landing time

Departure Node
- target takeoff time
- gate IN time
- gate time separation

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

Arrival Node
- landing time
- arrival

Gate Node
- pushback ready time
- departure

Departure Node
- target takeoff time
- gate IN time

Predicted Gate Conflict

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

time

$\beta$
Gate Conflict Resolution

Resolution Options
- Departure Early Release
- Departure To Hardstand
- Arrival To Hardstand

Arrival Node
- landing time

Departure Node
- target takeoff time
- gate IN time

Gate Node
- pushback ready time
- target gate release time

arrival

departure

β
Gate Conflict Resolution

Arrival Node

landing time

Departure Early Release

target takeoff time

gate IN time

Gate Node

pushback ready time

departure

\[ \beta \]
Gate Conflict Resolution

- **Arrival Node**
  - landing time
- **Departure Node**
  - departure
- **Hardstand Node**
  - pushback ready time
- **Gate Node**
  - departure

- **Gate IN time**
- **target takeoff time**
- **hardstand release time**

\[ \beta \]
Gate Conflict Prediction

Arrival Node

- landing time

Departure Node

Arrival To Hardstand

- hardstand release time

Hardstand Node

- pushback ready time

Gate Node

- departure

- target gate 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>
<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

**Demand Scenario**

- Ops per 15-min
- Simulation time (minutes)

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

Surface congestion uncertainty modelled
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

- **Arrival and Departure To Hardstand**
  - **Dual Hardstand**
  - **Arrival Hardstand**
  - **Departure Hardstand**
  - **None**
  - **No Hardstand**

- **actual gate separation - $\beta$**
  - **separation violation**
  - **excess separation**

- **Gate Time Separation**
  - **Actual gate separation**
  - **Excess separation**
  - **Violation**
  - **Release**
Results: Gate Time Separation

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

Runway Time Prediction Error at Ready Time

Error (min) | Average
---|---
late | Departures involved in gate conflict
early | Other departures

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

### Runway Time Prediction Error at Ready Time

<table>
<thead>
<tr>
<th>Error (min)</th>
<th>Average</th>
<th>Standard Deviation</th>
</tr>
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<tbody>
<tr>
<td>early</td>
<td></td>
<td></td>
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<tr>
<td>late</td>
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</tbody>
</table>

#### Departures involved in gate conflict
- Other departures

#### Other departures

<table>
<thead>
<tr>
<th>No HS</th>
<th>Dep HS</th>
<th>Arr HS</th>
<th>Dual HS</th>
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<th>Arr HS</th>
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</tbody>
</table>
Results: Runway Time Predictability

Runway Time Prediction Error at Ready Time

Average

Standard Deviation

Error (min)

late

early

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

Departures
(time between ready and takeoff)

<table>
<thead>
<tr>
<th>Departures</th>
<th>Average transit time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No HS</td>
<td>10</td>
</tr>
<tr>
<td>Dep HS</td>
<td>10</td>
</tr>
<tr>
<td>Arr HS</td>
<td>12</td>
</tr>
<tr>
<td>Dual HS</td>
<td>10</td>
</tr>
</tbody>
</table>

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

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