Modelling and Simulating Airport Surface Operations with Gate Conflicts

Shannon Zelinski
Robert Windhorst

NASA Ames Research Center

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
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
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
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)
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**
  - Departure
  - Pushback ready time
  - Target gate release time

- **Gate Node**
  - Target takeoff time

- **Time**
Gate Conflict Prediction

Arrival Node

- landing time
- arrival

Gate Node

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

Departure Node

- target takeoff time

Gate IN time

Time
Gate Conflict Prediction

Predicted Gate Conflict

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

- Arrival Node
  - landing time

- Departure Node
  - target takeoff time

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

- $\beta$
Gate Conflict Resolution

Resolution Options

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

Arrival Node
- landing time
- arrival

Departure Node
- target takeoff time
- surface

Gate Node
- pushback ready time
- departure
- gate IN time
- target gate release time

$\beta$
Gate Conflict Resolution

Arrival Node
- arrival
- landing time

Departure Node
- target takeoff time
- gate IN time

Gate Node
- departure
- pushback ready time

Departure Early Release

$\beta$
Gate Conflict Resolution

Arrival Node
- arrival
- landing time

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

Hardstand Node
- pushback ready time
- departure

Gate Node
- pushback ready time
- gate IN time

\[ \beta \]
Gate Conflict Prediction

Arrival Node
- landing time
- arrival

Departure Node
- pushback ready time
- departure

Hardstand Node
- hardstand release time
- target takeoff time

Gate Node
- target gate release time
- time

Arrival To Hardstand
## 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><strong>No Hardstand</strong></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Departure Hardstand</strong></td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td><strong>Arrival Hardstand</strong></td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td><strong>Dual Hardstand</strong></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

- **arrivals**
- **departures**

Surface congestion uncertainty modelled

**Demand Scenario**

<table>
<thead>
<tr>
<th>Simulation time (minutes)</th>
<th>Ops per 15-min</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>60</td>
<td>20</td>
</tr>
<tr>
<td>90</td>
<td>10</td>
</tr>
<tr>
<td>120</td>
<td>5</td>
</tr>
<tr>
<td>150</td>
<td>0</td>
</tr>
<tr>
<td>180</td>
<td>5</td>
</tr>
<tr>
<td>210</td>
<td>10</td>
</tr>
<tr>
<td>240</td>
<td>20</td>
</tr>
</tbody>
</table>

**Schedulers**
- Called every 10 seconds
- Surface metering ON
- Gate conflict $\beta = 5$ min
- 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 Hardstand**: Departure Early Release
- **Arrival Hardstand**: Arrival To Hardstand
- **Dual Hardstand**: Arrivals and Departures To Hardstand

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></th>
<th>Dual Hardstand</th>
<th>Arrival Hardstand</th>
<th>Departure Hardstand</th>
<th>No Hardstand</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Arrival and Departure To Hardstand</strong></td>
<td>![X marks]</td>
<td>![X marks]</td>
<td>![X marks]</td>
<td>![X marks]</td>
</tr>
<tr>
<td><strong>Arrival To Hardstand</strong></td>
<td>![X marks]</td>
<td>![X marks]</td>
<td>![X marks]</td>
<td>![X marks]</td>
</tr>
<tr>
<td><strong>Departure To Hardstand</strong></td>
<td>![X marks]</td>
<td>![X marks]</td>
<td>![X marks]</td>
<td>![X marks]</td>
</tr>
<tr>
<td><strong>None</strong></td>
<td>![X marks]</td>
<td>![X marks]</td>
<td>![X marks]</td>
<td>![X marks]</td>
</tr>
<tr>
<td><strong>Departure Early Release</strong></td>
<td>![X marks]</td>
<td>![X marks]</td>
<td>![X marks]</td>
<td>![X marks]</td>
</tr>
</tbody>
</table>

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

Error (min)

late

early

Average

Standard Deviation

Departures involved in gate conflict

Other departures

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

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

### Departures Involved in Gate Conflict (13)

### Other Departures (186)

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

Average transit time (min)

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

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

### Arrivals
(time between landing and gate)

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

---

**Flights involved in gate conflict**

**Other flights**

**Arrival resolution greatly impact arrival transit times**

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

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

Shannon.j.zelinski@nasa.gov