Development of Methods of Increasing Terminal Flexibility and Control Authority

NASA Contract: NNA14AC42C

Option Year 1 Final Presentation
September 30, 2016
Version #1

Architecture Technology Corporation
Outline

• Background and Overview of Departure Management What-if Analysis
• Option Year 1 Objectives and Accomplishments
• What-if Analysis Tool Enhancements
• Traffic and Weather Scenarios
• What-if Analysis Tool Verification
• What-if Evaluation Metrics
• What-if Evaluation Example
• What-if Analysis Tool Demonstration
• Recommendations
What-if Analysis Tool

Background

• NASA Airspace Technology Demonstration 2 (ATD-2)
  – Integrated arrival-departure-surface traffic management tools and operations enable ideal trajectories for departures
  – Delay at gate, unimpeded taxi on the airport surface, minimum time in departure runway queue, and continuous climb to cruise altitude
• FAA Surface Collaborative Decision Making (CDM) Concept of Operations
  – Departure Management Programs (DMPs) to provide strategic Target Movement Area Entry Times (TMATs) to control surface traffic levels
• Interfaces of NASA ATD-2 with FAA Surface CDM
  – Interface between Spot and Runway Departure Advisor (SARDA) runway takeoff and spot release sequence & schedule and DMP TMATs
  – Ramp control to meet strategic TMATs
• What-if analysis
  – Strategic planning of DMPs to mitigate effects of demand/capacity imbalances at airport under forecast operating conditions
Departure Metering What-if Analysis Concept Overview

**Far-term Time Horizon**
- Traffic Schedule
- Operating Conditions
- Departure Restrictions

**What-if Analysis Tool**

1. Assess impact on queue lengths, taxi time, gate delay, etc.
2. Analyze impact of potential changes to restrictions, runway rates, and scheduled traffic
3. Predict per runway need for DMP; DMP start time and duration
4. Evaluate effect of DMP parameters on managing demand/capacity imbalances and meeting airport performance objectives
5. DRC implements DMP during using selected parameters

**Departure Reservoir Coordinator (DRC)**

**Departure Metering System**

6. DMP specifies TMATs for departures as per near-term conditions
7. ATD-2 system performs integrated arrival-departure management

**Demand/Capacity Imbalance, Initial DMP Parameters**

**Target Movement Area Entry Times (TMATs)**

**ATD-2 Traffic Management System**

**Near-term Time Horizon**
- Traffic schedule
- Operating conditions
- Departure restrictions
Option Year 1 Objectives
SOW

• Develop and refine the what-if capability
  – Airport surface
  – Terminal airspace
  – Metrics and interfaces
  – Traffic and weather scenarios
  – DMP parameters and scope
• Use what-if analysis capability
  – Specify DMP parameters for CLT under different traffic and weather conditions impacting departure traffic flow
  – Evaluate effectiveness of DMPs in mitigating impacts of traffic flow inefficiencies
    • E.g., reducing delays during surface taxi & airborne transit

Final Briefing, 30 Sep 2016, Version 1
## Option Year 1

### Accomplishments

<table>
<thead>
<tr>
<th>Objective</th>
<th>Accomplishments</th>
</tr>
</thead>
</table>
| **Airport surface**              | • Investigated and documented CLT surface operations  
• Implemented node-link modeling of airport runways, spots and terminal gates for different configurations  
• Specified modeling parameters from CLT operations data and references, Base Year analyses  
• Verified implementation of models, compared simulation results to FAA ASPM  
• Developed detailed models of traffic flow interactions of runways, taxiways, non-movement area |
| **Terminal airspace**            | • Implemented and verified modeling of time period miles-in-trail restrictions for departure fixes  
• Implemented and verified miles-in-trail restrictions for departure runways to meet fix restrictions  
• Modeled link transit times from Base Year high-fidelity departure simulation data |
| **Metrics & interfaces**         | • Implemented metrics and interfaces for DRC to assess airport departure and arrival traffic flow and design DMPs  
• Implemented interfaces to configure and conduct What-if analysis and assess results |
| **DMP parameters & scope**       | • Summarized specifications for DMPs from FAA Surface Collaborative Decision Making ConOps  
• Implemented explicit control of Target Departure Queue Length for individual departure runways  
• Implemented methods to accommodate multiple flow restrictions on departures  
• Implemented automatic DMP start & end times from runway queue data |
| **Traffic & weather scenarios**  | • Identified recent operational days for idealized traffic schedule and traffic “disturbance” scenarios  
• Created input files for What-if Tool from traffic and restrictions data for those days |
| **DMP Evaluations**              | • Used What-if analysis tool to conduct demand analysis and DMP implementation for different historical and notional traffic & weather scenarios  
• Documented results & developed demonstrations |
What-if Analysis Tool Capabilities

• Adapt to changes in airport and airspace operating conditions
  – Runway configurations & rates
  – Traffic levels & airport/airspace resource utilizations
  – Departure fix restrictions

• Design & emulate Departure Management Program
  – Scheduling of gate pushback times & TMATs
  – Meter flights to control runway queue length
  – Account for per-runway departure rates & multiple departure restrictions

• Rapidly evaluate airport traffic performance
  – Evaluate variety of operating and DMP alternatives and uncertainty
  – DMP go-no go screening, start & end times, particular runways

• Present key departure and arrival performance metrics for detailed and aggregate performance assessment
  – Metrics important to airport operations
  – Nature of demand characteristics and airport traffic response
  – Time period- and runway-based assessment for detailed understanding
  – Aggregate assessment for comprehensive overview
CLT Airport Modeling Enhancements

- Node-link modeling of airport and airspace
  - Synthesized from gate/spot/runway/fix routes of flights in traffic file
  - Provides modeling flexibility to balance fidelity with simulation time

- Nodes
  - Queueing points where congestion occurs
  - Nodes
    - Gates, spots, runways, arrival and departure fixes abstracted as nodes
  - Parameters
    - Aircraft service time, $T_s$
    - Maximum queue size, $Q_{max}$
  - First in first out at specified service rate
  - Traffic in-flow versus out-flow determines flight delay

- Links
  - Transit segments between nodes
  - Parameter
    - Transit Time $T_T$

Entities modeled as nodes

Max queue size $Q_{MAX}$ (if any)

Aircraft served at rate $T_s$

Empty queue slots

Aircraft waiting in queue

Transit time $T_T$

Arbitrary route system geometries may be modeled
Node-link modeling of gate-spot-runway routes

- **Runway node**
- **Spot-runway link**
- **Spot node**
- **Gate-spot link**
- **Gate nodes**

- **Nodes**: traffic interaction & rate limits
- **Links**: undelayed transit

**Terminal Charts - PARKING GATES**

**Ramp Control**
- **North**: 130.07
- **South**: 131.6
- **East**: 129.22
- **West**: 129.8

**Dual Taxi between Departure Call Spots**
- 11/12 and 13N/13S restricted to aircraft with wingspans less than 171' (52m).
- Dual Taxi between Departure Call Spots 22/23 and 24N/24S restricted to aircraft with wingspans less than 118' (36m).
CLT Terminal Airspace Departure Modeling Example

Node-link modeling of runway-fix routes

- Nodes: traffic interaction & rate limits
- Links: undelayed transit

Departure fix node

Runway-fix link

Runway node
# CLT Node & Link Parameters/Attributes/Behavior

<table>
<thead>
<tr>
<th>Node type</th>
<th>Service time, Minutes</th>
<th>Size limit, aircraft</th>
<th>Data source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gate</td>
<td>30.0</td>
<td>1</td>
<td>Estimation</td>
</tr>
<tr>
<td>Spot</td>
<td>1.0</td>
<td>N/A</td>
<td>Estimation</td>
</tr>
<tr>
<td>Runway</td>
<td>2.0</td>
<td>N/A</td>
<td>30 aircraft/hour</td>
</tr>
<tr>
<td>Fix</td>
<td>1.7</td>
<td>1</td>
<td>SME-specified 7 miles @ 250 knots</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Link type</th>
<th>Transit time, minutes</th>
<th>Data source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gate-spot</td>
<td>4.0</td>
<td>SOSS simulation of CLT</td>
</tr>
<tr>
<td>Spot-runway</td>
<td>2.0</td>
<td>SOSS simulation of CLT</td>
</tr>
<tr>
<td>Runway-fix</td>
<td>14.0</td>
<td>Flight simulations of MERIL departures</td>
</tr>
</tbody>
</table>

- **Service time**: Minimum time to process aircraft, models rate limit of traffic passing through node, e.g., time interval of runway departure rate, in-trail spacing of departures crossing fix
- **Size limit**: Number of aircraft that can be waiting for service, e.g., number of departures that taxiway can fit, number of aircraft that can occupy terminal gate
- **Transit time**: Undelayed transit time between nodes
CLT Specialized Node Models

• Runway nodes
  – Node exit time for departures as per
    • Node service time
    • Service time for miles-in-trail restrictions at departure fix

<table>
<thead>
<tr>
<th>Fix</th>
<th>Miles In Trail</th>
<th>Time Start, Min</th>
<th>Time End, Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>MERIL</td>
<td>20</td>
<td>50</td>
<td>150</td>
</tr>
<tr>
<td>BUCKL</td>
<td>15</td>
<td>75</td>
<td>200</td>
</tr>
</tbody>
</table>

• Gate nodes
  – Departure entry/exit times fixed
    • Entry at scheduled gate entry time
    • Exit at gate occupancy time or DMP-scheduled pushback time
  – Arrivals delayed entry to gate until occupancy time window is available
What-if Tool Enhancements
DMP Emulation

Key Features

• Generates TMATs to absorb delay at the gate
• Satisfies multiple constraints
  – Minimum Gate Occupancy Spacing
  – Minimum Departure Spacing at Runways
  – Departure Fix Flow Restrictions
• Attempts to maintain a specified runway queue size
• **High Level Functionality**
  – Three main components

Component 1:
- Sort Flights by reference Points
- Runways
- Flow Restrictions

Component 2:
- Sort and Space Flights by time at each reference point
- Initial Attempt at full schedule solution

Component 3:
- ‘Fine-tunes’ schedule through iteration until all constraints are satisfied
- Iterative Spacing Routine
- Remaining Conflicts
DMP Emulation
Process Steps

- Step 1: Sort by Reference Point
- Step 2: Initial Sorting and Spacing
- Step 3: Iterative solution for convergence
DMP Emulation
Aircraft Spacing Algorithm

Sorted but not spaced

Spaced

- \( \Delta t_{sp} \)
- \( \Delta t_{sp} \)
- \( \Delta t_{sp} \)
- \( \Delta t_{sp} \)

Start

\( i=1 \)

More Flights ?

\( \text{yes} \)

Get ith Flight

Advance i

Get i+1 Flight

Is flight (i+1) spacing after (ith) sufficient?

\( \text{yes} \)

Explicit algorithm

\( \text{no} \)

Add Delay until i+1 spacing behind ith is sufficient

Stop

\( \text{no} \)

Get i+1 Flight

Is flight (i+1) spacing after (ith) sufficient?

\( \text{no} \)

Add Delay until i+1 spacing behind ith is sufficient

Existing spacing

Algorithm is the same regardless of reference point

minimum required spacing

\( \Delta t_{space} = t_{i+1}^{i+1} - t_{i}^{i} \)

\( \text{if} \ (\Delta t_{space} < \Delta t_{sp}) \Rightarrow \Delta t_{delay} = \Delta t_{sp} - \Delta t_{space} \)

\( t_{gate-exit} + \Delta t_{delay} \)

\( t_{runway} = t_{gate-exit} + \Delta t_{gate-rwy \ transit} + \Delta t_{delay} \)

\( t_{dep-fix} = t_{runway} + \Delta t_{rwy-fix \ transit} + \Delta t_{delay} \)

Delay is always added at the gate and cascades through all downstream reference points
Aircraft queue, q, forms when supply rate, r\textsubscript{in}, exceeds service rate, r\textsubscript{out},

\[ q = \int (r_{in} - r_{out}) \, dt \]

Supply & service rates \( r_{in} \) & \( r_{out} \) as inter-flight times \( \Delta t_{sp} \) & \( \Delta t_{rwy} \)

Queue size, \( q_i \), feedback control of supply rate/spacing, \( \Delta t_{sp} \), to meet target queue size, \( q_t \)

Delay aircraft queue entry time as needed to satisfy inter-aircraft supply spacing, \( \Delta t_{sp} \)
Traffic & Weather Scenarios
Development Methods

• Information sources for scenario initialization
  – Weather Underground for historical weather to select scenario days
  – ASDI in-bound fix/TRACON entry fix position and time (ATA) data
  – Out/Off/On/In (OOOI) from a major CLT airline operator for August 2014*
  – NASA Restrictions May through Dec 2014
    • Expected Departure Clearance Time (EDCT)
    • Call for Release (CFR)
    • Miles in Trail (MIT): used fix location and miles spacing values
  – Ramp controller procedures to infer spot allocation

• Scenario preparation methodology
  – Capture all arrivals/departures from 5 AM to midnight
  – Infer tail number connectivity by associating scheduled gate IN-OUT times per gate and aircraft type
  – Start time for each departure based on IN time of associated arrival
  – Spot assignments from airport layout, gate/runway pairs and airline Standard Operating Procedures (SOP)

* Note: Boeing obtained Official Airline Guide (OAG) data for the 3rd quarter of 2014 as reported in the “Traffic and Weather Identification and Modeling Document (Contract CDRL 4.6). However, the team relied entirely on the out/off/on/in (OOOI) schedule data to build the scenario.
Traffic & Weather Scenarios
Reference Data For Days

Scenario Days

<table>
<thead>
<tr>
<th>Type</th>
<th>Date in 2014</th>
<th>Weather at CLT</th>
<th># of EDCT</th>
<th># of CFR</th>
<th># of MIT restrictions</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline (Good Weather)</td>
<td>August 8</td>
<td>Clear, visibility of 8 NM</td>
<td>4</td>
<td>25</td>
<td>42</td>
<td>Usual restrictions for CLT</td>
</tr>
<tr>
<td>Disruptive Events (Bad Weather)</td>
<td>August 11</td>
<td>Rainfall at CLT reduces visibility to 1 NM</td>
<td>1</td>
<td>25</td>
<td>45</td>
<td>Storm moving through CLT</td>
</tr>
<tr>
<td></td>
<td>August 15</td>
<td>VMC/VFR conditions, no flow reversals</td>
<td>7</td>
<td>42</td>
<td>76</td>
<td>Weather near Atlanta with restrictions imposed by Atlanta ARTCC</td>
</tr>
<tr>
<td></td>
<td>August 18</td>
<td></td>
<td>2</td>
<td>41</td>
<td>180</td>
<td>Heavy volume restrictions due to extreme rainfall in TN and NE Alabama</td>
</tr>
</tbody>
</table>

CLT Operational Constraints Arrival Flows & TRACON Fixes

Note: entry/exit fix positions are outside the diagram and are represented notionally.
Weather and Traffic Scenarios
Departure Fix Restrictions

- CLT Departure Traffic With Restrictions for 8/18/2014
  - What-if tool models MIT restrictions

<table>
<thead>
<tr>
<th>Fix</th>
<th>Miles In Trail</th>
<th>Time Start, Min</th>
<th>Time End, Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>MERIL</td>
<td>10</td>
<td>554</td>
<td>559</td>
</tr>
<tr>
<td>MERIL</td>
<td>15</td>
<td>570</td>
<td>732</td>
</tr>
<tr>
<td>MERIL</td>
<td>15</td>
<td>780</td>
<td>970</td>
</tr>
<tr>
<td>MERIL</td>
<td>20</td>
<td>970</td>
<td>1005</td>
</tr>
<tr>
<td>MERIL</td>
<td>25</td>
<td>1005</td>
<td>1090</td>
</tr>
<tr>
<td>MERIL</td>
<td>25</td>
<td>1139</td>
<td>1261</td>
</tr>
<tr>
<td>MERIL</td>
<td>10</td>
<td>475</td>
<td>505</td>
</tr>
<tr>
<td>MERIL</td>
<td>15</td>
<td>1100</td>
<td>1185</td>
</tr>
</tbody>
</table>
Histogram of scheduled gate departure times for 8/8/2014 baseline traffic scenario
What-if Analysis Tool Verification

- Traffic Simulation
  - Parameter adherence
    - Verified traffic flow adheres to link transit times, node service rates, node queue length limits, departure fix restriction spacing & time period
  - Comparison to FAA ASPM for 8 August 2014
    - Input traffic schedule
      - IN-OUT times differ from airline-scheduled times
    - Departure throughput & taxi-out times
      - Departure rates: Comparable maximum and total average, different hourly averages
      - Taxi-out times: Comparable hourly and total averages
    - Arrival throughput & taxi-in times
      - Arrival rates: Comparable maximum, hourly and total averages
      - Taxi-in times: Simulation higher due to gate occupancy and utilization modeling
- DMP Emulation
  - Parameter adherence
    - Verified scheduled departures adhere to runway rates, departure fix restrictions and gate occupancy restrictions
  - Traffic control
    - Verify metering meets traffic performance requirements
Airport Evaluation Metrics
Runway Demand & Capacity

Time-bin traffic demand for each runway

Per-runway capacity

Arrivals

Per-runway capacity of 7-8 aircraft/quarter hour

Departures

Per-runway capacity of 7-8 aircraft/quarter hour
Airport Evaluation Metrics
Departure Performance

Key performance metrics of throughput, congestion, taxi time and gate delay

Airport runway traffic performance for detailed understanding of operations

Time-bin presentation to see trends & variability

Limits for comparison

Time period presentation to know total performance

<table>
<thead>
<tr>
<th>Departure Runway</th>
<th>Average Throughput, Departures Per Hour</th>
<th>Average Queue Length, Departures</th>
<th>Maximum Queue Length, Departures</th>
<th>Minimum Queue Length, Departures</th>
<th>Average Taxi Out Time, Minutes</th>
<th>Average Gate Delay, Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>18C</td>
<td>29</td>
<td>3</td>
<td>12</td>
<td>0</td>
<td>23.6</td>
<td>0</td>
</tr>
<tr>
<td>18L</td>
<td>26</td>
<td>9</td>
<td>25</td>
<td>0</td>
<td>41.9</td>
<td>0</td>
</tr>
</tbody>
</table>
Airport Evaluation Metrics
Arrival Performance

Key performance metrics of throughput and taxi time

Airport runway traffic performance for detailed understanding of operations

Time-bin presentation to see trends & variability

Time period presentation to know total performance

<table>
<thead>
<tr>
<th>Arrival Runway</th>
<th>Average Throughput, Arrivals Per Hour</th>
<th>Average Taxi In Time, Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>18C</td>
<td>29</td>
<td>23.6</td>
</tr>
<tr>
<td>18L</td>
<td>26</td>
<td>41.9</td>
</tr>
</tbody>
</table>
Scenario

Example Evaluation

Traffic Schedule

Departure Restrictions

- Restrictions due to nearby rainstorms on August 18, 2014, 2:08 p.m. to 5:58 p.m. local CLT time

What-if Analysis Tool
What-if Evaluation, Airport Demand Analysis

Departure Demand

Departures push back at airline-scheduled times

Demand intermittently exceeds RDR of 7-8 aircraft/quarter hour

Airport Departure Performance

- Runway throughput intermittently saturates
- Runway departure queues exceed target length
- Runway departures exhibit excessive taxi-out times
What-if Evaluation, DMP Analysis

**Departure Demand**

Departures push back at DMP-scheduled times
- Start: 60 min
- End: 289 min

Demand more closely complies with RDR of 7-8 aircraft/quarter hour

**Airport Departure Performance**

- Runway throughput maintained
- Runway departure queues closer to target length
- Average taxi-out times reduced
- Gate holding delay introduced
What-if Evaluation Comparison, Departures

- Departure metering program effective
  - Runway departure throughput maintained
  - Runway queue lengths reduced

- More significant reductions for runway 18L departures
  - Arrivals to runway 18C interfering with planned runway departure rate

- Average taxi-out times reduced
  - More significant reduction of 4.5 minutes for departures from runway 18L
  - Arrivals to 18C impacting departure taxi-out delay
What-if Evaluation Comparison, Arrivals

- **Arrival taxi-in time increases due to departure gate holding**
  - Average taxi-in delay increase due to increased gate occupancy of departures
Tool Demonstration

• Test case of delaying DMP start time
  – Traffic schedule
    • hitl6-training-advisory.list_data
    • CLT south flow
    • Departures: 52 from 18L, 37 from 18C
    • Arrivals: 41 from 18R, 38 from 23
  – Departure restrictions
    • TrafficFlowRestrictions.csv

<table>
<thead>
<tr>
<th>Fix</th>
<th>Miles In Trail</th>
<th>Time Start, Min</th>
<th>Time End, Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>MERIL</td>
<td>20</td>
<td>50</td>
<td>150</td>
</tr>
<tr>
<td>BUCKL</td>
<td>15</td>
<td>75</td>
<td>200</td>
</tr>
</tbody>
</table>

– Departure management program
  • Start time, min: 60, 30
Summary

• Developed and demonstrated prototype What-if Analysis Tool for strategic assessment of airport traffic and planning of DMPs/TMATs
  – Adaptable to forecast airport operating conditions
  – Rapid evaluation of traffic
  – Emulation of DMP
  – Metrics & presentation to understand traffic behavior & assess airport performance
  – Supports exploring airport traffic behavior & DMP implementation
• Applied to realistic and notional traffic and weather scenarios
  – Effective in planning the management of departures & arrivals
  – Evaluating complicating factors of uncertainty in operating conditions
Conceptual User Interface
Recommendations
What-if Operations

• Forecasting, what-if analysis and DMP implementation to proactively minimize the negative impact of changing weather, airport and traffic conditions
  – Forecasting traffic flow restrictions, traffic conditions, and airport operating conditions & estimating uncertainties of forecasts
  – What-if analysis tool and process to design DMPs to accommodate forecasts
  – Categorical (fix specific) DMPs along with other runway-specific DMPs or destination-specific TMI s for departures subject to particular restrictions
  – Collaboration of DRC with aircraft operators and other stakeholders in the what-if analysis and DMP implementation decision making
Recommendations
What-if Tool

• Airport & airspace modeling
  – Departure restrictions: other types, assignment to specific tail numbers
  – Surface traffic interaction points which impede flow
  – Gate modeling: assignment alternatives for arrivals, trail tracking for detailed impact on aircraft utilization
  – Variability in runway departure rates, transit times, gate occupancy times
  – Verification: flight taxi times as per OOOI data, use delay fields from SWIM/FIXM data as a source

• DMP emulation
  – Individual runways, departure runways shared with arrivals
  – Alternative implementation for distinct constraints

• Traffic & weather scenarios
  – Additional scenarios including Lower visibility weather conditions at CLT, North Flow runway operations, recovery from Ground Stop
  – Design around traffic patterns of interest
• Differences between hourly counts of scheduled arrivals & departures between FAA ASPM data and traffic schedule input to simulation
  – Traffic schedule input file derived from OOOI data, not schedule data
  – May impact comparison of hourly statistics computed from simulation output data
Verification Results
Traffic Output From Simulation

Simulated vs. FAA ASPM hourly takeoff rates differ significantly in many hours

Simulated vs. FAA ASPM hourly taxi-out times comparable in many hours

<table>
<thead>
<tr>
<th>Source</th>
<th>Average Departure Throughput, Departures Per Hour</th>
<th>Average Taxi Out Time, Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAA ASPM, 8 August 2014</td>
<td>45</td>
<td>16.0</td>
</tr>
<tr>
<td>What-if Tool Traffic Simulation</td>
<td>36</td>
<td>15.9</td>
</tr>
</tbody>
</table>

- Simulated vs. FAA ASPM aggregate departure rates somewhat lower
- Simulated vs. FAA ASPM aggregate taxi-out times comparable
Scatter plot of actual departure taxi times by spot/runway assignment for 8/8/2014 baseline scenario
Traffic & Weather Scenarios
Baseline Scenario Surface Traffic

Scatter plot of actual departure taxi times overlaid onto histogram of gate scheduled departure times for 8/8/2014 baseline scenario

Histogram: number of scheduled departures by ¼ hour
Scatter Plot: departure taxi times for potential future analysis & comparison
• DMP results for simple test case *hitl6-training-advisory.list_data*
  – Throughput maintained
  – Runway queue lengths comply with the target of 3/+1-2 aircraft
  – Average quarter-hour taxi-out times departures are sharply reduced
  – Taxi-out delay shifted to gate
### Airport Demand Analysis

**Select initial scenario information**

- Traffic Schedule File: C:\Work\Terminal\Control\What If CY1\Scenario\Files\Sensitivity\HTB-training-advisor.txt
- Flow Restrictions File: C:\Work\Terminal\Control\What If CY1\Scenario\Files\Sensitivity\TrafficFlowRestrictionsShort.csv

**Simulation & Results Configuration**

- Simulation Time Step (mins): 1
- Plot Time-Bin Size (mins): 15

**Choose airport/airspace parameter values for demand what-if analysis**

<table>
<thead>
<tr>
<th>Runway</th>
<th>Departure Rate</th>
<th>Departure Fix</th>
<th>MFI Restriction</th>
<th>Start Time</th>
<th>End Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>18C</td>
<td>30</td>
<td>MER16</td>
<td>20</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>18L</td>
<td>30</td>
<td>BUCK17</td>
<td>15</td>
<td>75</td>
<td>130</td>
</tr>
</tbody>
</table>

**Demand analysis results**

<table>
<thead>
<tr>
<th>Departure Runway</th>
<th>Ave Throughput</th>
<th>Ave Queue Length</th>
<th>Max Queue Length</th>
<th>Min Queue Length</th>
<th>Ave Taxi Out Time (min)</th>
<th>Ave Gate Delay (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18C</td>
<td>29.2105</td>
<td>2.9728</td>
<td>12</td>
<td>0</td>
<td>23.5761</td>
<td>8.0417e-10</td>
</tr>
<tr>
<td>18L</td>
<td>27.3604</td>
<td>9.0380</td>
<td>25</td>
<td>0</td>
<td>39.7482</td>
<td>1.09316e-15</td>
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<table>
<thead>
<tr>
<th>Arrival Runway</th>
<th>Ave Throughput</th>
<th>Ave Taxi In Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18R</td>
<td>26.5116</td>
<td>12</td>
</tr>
</tbody>
</table>

### DMP Analysis

**Choose parameters for DMP what-if analysis**

- Runway: 18C
- Target Departure Queue Length: 3
- Start Time: 70
- Stop Time: 183

**OMP what-if analysis results**

<table>
<thead>
<tr>
<th>Departure Runway</th>
<th>Ave Throughput</th>
<th>Ave Queue Length</th>
<th>Max Queue Length</th>
<th>Min Queue Length</th>
<th>Ave Taxi Out Time (min)</th>
<th>Ave Gate Delay (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18C</td>
<td>29.2105</td>
<td>2.9728</td>
<td>12</td>
<td>0</td>
<td>23.5761</td>
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</table>

**Arrival Runway Analysis**

<table>
<thead>
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<th>Arrival Runway</th>
<th>Ave Throughput</th>
<th>Ave Taxi In Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18R</td>
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<td>15.7073</td>
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<tr>
<td>23</td>
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