Benefits Assessment Methodology for an Air Traffic Control Tower Advanced Automation System

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Outline

• Overview of system

• Need for benefits assessment

• Methodology

• Application/Data analysis

• Results: Informing system development priorities

• Summary
Tower Flight Data Manager (TFDM)

- Integrated tower system being considered for development by FAA

External Sources
- Terminal and Surface Surveillance
- Flight Plan Data
- Traffic Flow Constraints
- Flight Operations Data
- Weather / Hazards

Enablers
- Consolidated tower systems
- Enhanced cross-domain information exchange
- Decision support tools

Benefits
- Robust operations
- Reduced delay, fuel, environmental impact
- Enhanced safety
- Ability to support remote operations: Staffed NextGen Tower (SNT)

Operational Users
- Tower controllers
- Flight data, Clearance, Ground, Local, Supervisor
- TRACONs, ARTCCs
- Flight Operations Centers
- Ramp Tower
- Airport Authority

Tower Flight Data Manager
- Decision Support Tools (DSTs)
- Remote / Enhanced Visual Awareness

Net-centric Infrastructure

Surveillance Display

Flight Data Manager

Decision Flow Constraints
Need for Benefits Assessment

- Quantifies how well the new system performs relative to baseline
- Needed for Investment Analysis to make business case for continued development and/or deployment
- Leads to understanding of system inefficiencies and causality to help guide capability development
FAA Standard Benefits Assessment Methodology

- FAA defines 11-step benefits analysis methodology

- Distilled version:
  1. Understand the program
  2. Identify relevant performance metrics
  3. Identify current & future “baseline” system performance
  4. Identify current & future “new” system performance
  5. Define the benefits impact
  6. Convert to economic values and compare to costs
  7. Report
TFDM Benefits Assessment Methodology

1. Understand the new system
2. Identify relevant metrics
3. Establish baseline metric values
4. Establish new system metric values
5. Define the benefits impact
6. Convert to economic values and compare to costs
7. Report

- 1. ConOps Functional Reqs Operational Assessment
- 2. Metric Identification
- 3a. Current Baseline System Metric Predictions
- 3b. Future Baseline System Metric Predictions
- 4a. TFDM Capability Development
- 4b. Future TFDM System Metric Predictions (Alternative 1..n)
- 5a. Benefits Claimed by Other Systems
- 5b. TFDM Benefits
- 6a. TFDM Costs
- 6b. TFDM Cost / Benefit Analysis
- 7. Report
TFDM Benefits Assessment Methodology
Application

- Step 1: Primary objective of TFDM is to improve efficiency of surface operations

- Step 2: Taxi-out delay time & fuel burn performance metrics

- Step 3a: Current baseline system performance
  - ASPM analysis
  - ASDE-X analysis

- Step 3b: Future baseline system performance
  - Queuing model

- Step 4a: Informing TFDM capability development

- Step 4b: Future TFDM system performance

- Step 5/6/7: TFDM cost/benefit analysis and report
Current Baseline System Performance
ASPM Analysis

• FAA Aviation System Performance Metrics (ASPM) data extracted for analysis airports

• Taxi-out delay time: average versus unimpeded push-back-to-wheels-off time

• Taxi-out delay fuel: Delay time x Fleet-mix-weighted fuel flow
  – Fuel flow for individual aircraft from ICAO ground idle rate
  – Assumes all delay absorbed with engines on (upper bound)
Current Baseline System Performance
ASPM Analysis (2008)

Average total delay: 2533 hrs/day (925 khrs/yr), 1874 tonnes/day (684 ktonnes/yr)
Current Baseline System Performance
ASDE-X Analysis

- Airport Surface Detection Equipment-Version X (ASDE-X) surveillance allows identification of location of delay on surface
  - Gate
  - Spot
  - Queue
  - Runway

- At these locations, inefficiencies can be observed & control mechanisms applied

- ASDE-X data from Dallas-Fort Worth (DFW) airport analysed
  - TFDM prototype site
Current Baseline System Performance
ASDE-X Analysis

Performance Metric:
- e.g. Total Taxi-out Time

Gate

Spot

Runway Queue

Runway Enter

Wheels-off

Benefit gained from TFDM

Alternative n

Remaining “avoidable” delay

“Unavoidable” delay

Taxi-out Delay “Benefits pool”

“Ideal” system

Spot delay

Runway queue delay

Position & hold

Ramp Taxi Runway Queue

MIT Lincoln Laboratory
Current Baseline System Performance
ASDE-X Analysis

- ASDE-X observed delay: 6.1 mins
- ASDE-X delay wrt 10th %ile: 4.1 mins
- ASPM delay wrt 10th %ile: 4.3 mins

<table>
<thead>
<tr>
<th>Taxi-out Delay (mins)</th>
<th>VMC n≈3000</th>
<th>IMC n≈1500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative to Unimpeded</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Runway, 0.8</td>
<td>Runway, 1.0</td>
</tr>
<tr>
<td></td>
<td>Queue, 2.0</td>
<td>Queue, 4.0</td>
</tr>
<tr>
<td></td>
<td>Taxi, 1.0</td>
<td>Taxi, 1.1</td>
</tr>
<tr>
<td></td>
<td>Ramp, 2.2</td>
<td>Ramp, 3.5</td>
</tr>
</tbody>
</table>

VMC n≈3000
IMC n≈1500
Future Baseline System Performance
Queuing Model

• Investment analysis period: 2015-2035

• Queuing model developed to project taxi-out delay time & fuel at analysis airports into future

• Assumptions:
  – Runway is dominant airport constraint
  – Poisson demand rates
  – Exponentially-distributed service times

• Model inputs:
  – Demand: FAA Terminal Area Forecast
  – Capacity: FAA FACT2 Airport Capacities (2007-2025, no increase 2025-2030)
  – Average delay capped at 15 mins in VMC and 45 mins in IMC (consistent with system evolving when delays increase)
Future Baseline System Performance
Queuing Model

Annual Runway Queueing
Delay Time Across 43 Airports
(Relative to 2008)

Year

2005 2010 2015 2020 2025 2030 2035 2040
Future Baseline System Performance
Queuing Model

- TFDM capabilities should be designed to deliver benefits against this portion

Cumulative Runway Queueing Delay Time Across 43 Airports (Relative to 2008)

% Cumulative Runway Queuing Delay Reduction

0 20 40 60 80 100

0 20 40 60 80 100

Unique savings available to TFDM (notional)

Claimed by other systems (notional)

Unavoidable Delay (notional)
Informing TFDM Capability Development

- Mapping delay location to possible causality

<table>
<thead>
<tr>
<th>Location of Delay</th>
<th>Identified Causes</th>
<th>TFDM Opportunities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ramp</td>
<td>Aircraft not ready</td>
<td>Situational awareness</td>
</tr>
<tr>
<td></td>
<td>Ground crew not ready</td>
<td>Situational awareness</td>
</tr>
<tr>
<td></td>
<td>Ramp blocked</td>
<td>Situational awareness</td>
</tr>
<tr>
<td></td>
<td>Forgotten at spot</td>
<td>Efficiency improvement</td>
</tr>
<tr>
<td></td>
<td>Back propagation of delay</td>
<td>Indirect impact</td>
</tr>
<tr>
<td>Taxi</td>
<td>Runway crossings required</td>
<td>Situational awareness</td>
</tr>
<tr>
<td></td>
<td>Long taxi route</td>
<td>Efficiency improvement</td>
</tr>
<tr>
<td></td>
<td>Taxiway capacity limit</td>
<td>Efficiency improvement</td>
</tr>
<tr>
<td>Queue</td>
<td>Runway crossings by others</td>
<td>Situational awareness</td>
</tr>
<tr>
<td></td>
<td>No airborne route available</td>
<td>Efficiency improvement</td>
</tr>
<tr>
<td></td>
<td>Runway capacity limit</td>
<td>Efficiency improvement</td>
</tr>
<tr>
<td></td>
<td>Inefficient departure sequence</td>
<td>Efficiency improvement</td>
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<tr>
<td>Runway</td>
<td>Aircraft not ready</td>
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<tr>
<td></td>
<td>Aircraft performance</td>
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Informing TFDM Capability Development

- Mapping causality to TFDM capability development opportunities

<table>
<thead>
<tr>
<th>Identified Causes</th>
<th>Benefits Mechanism</th>
<th>Candidate TFDM Capability</th>
<th>Key Enabling Capabilities</th>
<th>Observations &amp; Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forgotten at spot</td>
<td>Prevent waiting aircraft from being overlooked</td>
<td>Notify controllers when aircraft is at spot for long time</td>
<td>Predict normal spot wait time</td>
<td>Frequency of occurrence; Assess proper threshold</td>
</tr>
<tr>
<td>Long taxi route</td>
<td>Avoid long taxi routes if shorter alternatives exist</td>
<td>Assign efficient taxi routes, accounting for upcoming runway configuration changes</td>
<td>Predict upcoming RW configuration changes; Taxi time modeling</td>
<td>Presence of alternative routes; Taxi time model accuracy</td>
</tr>
<tr>
<td>Taxiway/runway capacity limit</td>
<td>Manage demand on taxiway/runway to match capacity</td>
<td>Recommend spot release times to meter surface traffic</td>
<td>Surface queuing models to predict congestion</td>
<td>Frequency of occurrence and correlated conditions; Ideal queue length</td>
</tr>
<tr>
<td>No airborne route available</td>
<td>Get aircraft to runway (only) when route is available</td>
<td>Predict route blockage and manage spot release time to achieve needed runway time</td>
<td>Departure route availability analysis; Taxi time modeling</td>
<td>Frequency of occurrence; Reliability of route availability forecasts</td>
</tr>
<tr>
<td>Inefficient departure sequence</td>
<td>Increase dep. seq. efficiency</td>
<td>Manage spot release times to improve sequence</td>
<td>Predict dep. sequence; Sequence optimization</td>
<td>Comparison to optimal sequence</td>
</tr>
</tbody>
</table>
Summary

• New integrated air traffic control automation system being developed

• Importance of benefits assessment in system development
  – Business case
  – Inform development priorities

• Methodology for benefits assessment presented, with sample applications and data analysis

• Illustrated insights for TFDM development