Airport Characterization for the Adaptation of Surface Congestion Management Approaches*

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Outline

• Motivation
• Framework for adapting surface congestion management approaches
• Airport characterization
  – Site visits
  – Surface visualizations
  – Operational data analysis
• Algorithm development
• Implementation design
• Testing and performance evaluation
Motivation: Scale of Problem

• Surface congestion increases taxi times, fuel burn and emissions
  – Nationally (2012 ASPM)
    • 31M min taxi-out delay; 15M min taxi-in delay
  – LGA (2012 ASPM)
    • 2M min taxi-out delay; 400K min taxi-in delay
    • 19K tons of fuel, 60K tons CO$_2$, 239 tons NOx, 127 tons HC
  – PHL (2012 ASPM)
    • 1.2M min taxi-out delay; 351K min taxi-in delay
    • 20K tons of fuel, 63K tons CO$_2$, 256 tons NOx, 150 tons HC
  – BOS (2012 ASPM)
    • 687K min taxi-out delay, 297K min taxi-in delay
    • 13K tons of fuel, 41K tons CO$_2$, 164 tons NOx, 83 tons HC

• Potential to mitigate these impacts through surface congestion management
Role of Departure Metering in Surface Congestion Management

- Departure metering just one element of required surface management toolset

- Departure metering manages pushbacks during congested periods
  - Decreased “engines-on” time, fuel burn & emissions

- In principle, can work at any congested airport, but details of successful implementation will vary
  - e.g., ATC facility vs. airline ramp tower

[A. Nakahara, 2012]
## Examples of Departure Metering Approaches

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Motivation: Need for Adaptation

- Prior surface congestion management efforts focused on specific airports
- Need to adapt approaches to multiple airports with different characteristics to gain system-wide benefits
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• **Framework for adapting surface congestion management approaches**

• **Airport characterization**
  – Site visits
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  – Operational data analysis

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• Testing and performance evaluation
Framework for Adapting Surface Congestion Management Approaches

- Airport Selection
- Airport Characterization
  - Site visits
  - Visualizations
  - Operational Data Analysis
- Algorithm Development
- Implementation Design
- Operational Testing & Performance Evaluation
- Refinement/Validation
- Results
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Airport Characterization: Site Visits

• Gain understanding of airport characteristics
  – Physical layout
  – Equipment levels
  – Air carrier and fleet mix
  – Other factors that influence throughput

• First-hand observations of operations
  – Standard procedures
  – Current challenges

• Expert opinions from ATC professionals
  – Explanation of operations
  – Answering congestion management questions
  – Identifying potential opportunities for mitigation
Sample Site Visit Observations: LGA

- Insights into:
  - Physical tower layout
  - ATC positions and relative locations
  - Equipment availability
  - Standard operating practices
Sample Site Visit Observations: LGA

- Typical taxi routes & surface congestion issues

Extended departure taxi route to queue aircraft during periods of high demand or with re-routes

Nominal departure taxi route via B and P

Queues observed to form short of taxiway GG (hand-off point between GCs)

Nominal arrival taxi route: depart 22, taxi via B and A

Single aircraft push-back fully blocks alley-way

Single aircraft push-back can block arrival taxi route
Airport Characterization: Surface Visualizations

• Use airport surveillance data archives (e.g., ASDE-X)
• Allows detailed observations for a range of airport operating conditions beyond those seen on site visits
• Surface procedures across configurations
  – Standard taxi routes
  – Runway entry, exit and crossing locations
  – Aircraft holding/queuing locations
• Dynamics of demand over extended time intervals
  – At gate
  – At terminal
  – At runway
• Dynamics of interactions between arrivals and departures
Sample Surface Visualization:
LGA 22 | 13
Sample Surface Visualization:
PHL 27R | 27 L
Sample Surface Visualization:
BOS 22L, 27 | 22R
Airport Characterization: Operational Data Analysis

- Historical data from ASPM and ASDE-X

- Quantification of airport characteristics & performance
  - Runway configuration breakdown
  - Traffic demand
  - Queue sizes
  - Taxi time
  - Airline mix

**BOS Runway Configuration Usage; 6/1/11-8/31/11**

**BOS Surface Metrics (22L,27|22R,22L); 6/1/11-8/31/11**

- Number of Active Departures
- Queue Size
- Taxi Time
Operational Data Analysis: Runway Configuration Use

- Congestion management needs to be tailored to dominant runway configurations
  - BOS: two dominant configurations
  - LGA: multiple configurations
  - PHL: one dominant configuration

LGA Runway Configuration Usage; 6/1/11-8/31/11

- 4 | 13: 12%
- 4 | 31: 37%
- 13 | 4, 13: 17%
- 31 | 4: 26%
- 22 | 13: 17%
- 22 | 31: 26%
- 22 | 22: 26%

PHL Runway Configuration Usage; 6/1/11-8/31/11

- 9R | 9L: 26%
- 27R | 27L: 77%
- 27L | 27L: 17%
- 9R | 9R: 17%
Operational Data Analysis: Airline Mix

- Congestion management implementation may vary significantly with airline mix
  - PHL: dominant carrier
  - BOS/LGA: mixed operators

All data from 6/1/11-31/8/11
Operational Data Analysis: Traffic Demand

- Characteristics of airport traffic for dominant configurations
  - Departure demand
  - Queue size
  - Taxi time

- Instrumental in tuning congestion management control variables and strategies
Operational Data Analysis: PHL Traffic Demand

PHL Average Number of Arrivals and Departures; 6/1/11-8/31/11

Number of Aircraft

Local time (hrs)
Operational Data Analysis: Throughput Saturation

- Differences between runway configurations at an airport
  - Departure rate
  - Saturation point
Airport Characterization: Implications for Congestion Management

- **BOS:**
  - Evening peak
  - Two main configurations
  - Mix of airlines
  - Aggregate solution, tailored to two runway configurations, primarily necessary in evening

- **LGA:**
  - Constant high demand
  - Mix of airlines/configurations
  - Aggregate solution, needed most of operating day

- **PHL:**
  - Intermittent peak demand
  - Dominant runway configuration
  - Dominant airline
  - Congestion management needed in demand peaks; potential for airline-specific solution
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Algorithm Development

- Algorithm concept

- Need curve characteristics for each airport/configuration

| Airport | Configuration (arrivals | departures) | Saturation point, $N^*$ (# active dep.) | Saturation Throughput, $T^*$ (ac/hr) |
|---------|-------------------------|----------------------------------------|-------------------------------------|
| BOS     | 4R, 4L | 9, 4R | 17 | 48 |
|         | 22L, 27 | 22R, 22L | 13 | 45 |
| LGA     | 22 | 13 | 11 | 36 |
|         | 31 | 4 | 15 | 40 |
|         | 22 | 31 | 18 | 42 |
|         | 4 | 13 | 15 | 36 |
| PHL     | 27R | 27L | 12 | 48 |
|         | 9R | 9L | 20 | 40 |
Algorithm Development: Parametric Dependencies of Throughput

- Departure throughput dependencies vary by airport
  - **BOS**: Arrival throughput, departure demand, departure fleet mix (props)
  - **LGA**: Arrival throughput, departure demand, departure route availability
  - **PHL**: Arrival throughput, departure fleet mix (props), fleet mix (Heavy aircraft), departure route availability

- Reliable throughput predictions are important for effective metering
  - To avoid low runway utilization
  - To avoid excessive surface congestion

(mean, std deviation) of departure throughput/15 min BOS in 22L, 27 | 22R, 22L under saturation

[I. Simaiakis, 2012]
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Implementation Design

- Airport/ATC tower operating characteristics
  - Ramp or FAA tower-controlled pushbacks
  - Tower layout and equipment

- Algorithm information input requirements
  - Capacity and demand forecasts

- Algorithm execution platform

- Algorithm output format

- Algorithm execution procedures

Tablet 1: Data input

Tablet 2: Recommended push-back rate display

BOS Tower Cab

Capacity (Airport config.), Weather (VMC/IMC)
Demand (Aircraft with Ground/Local Control, Expected arrivals)
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Operational Testing and Performance Evaluation

• Operational testing
  – Validity and robustness under actual operational conditions
  – Basis for refinement

• Benefits/cost assessment
  – Compare surface congestion metrics before/after deployment
  – Monetized benefits basis for investment analysis

• Airport operational efficiency
  – Runway utilization
  – Departure spacing
Sample Surface Visualization:
BOS 22L, 27 | 22R during Metering (2011)
Summary

- Surface congestion management important to fuel burn/emissions reduction at many airports
- Existing deployments focused on specific airports: techniques needed for adaptation to more airports and operating conditions
- Adaptation framework proposed
- Airport characterization is an important first step:
  - First-hand observations and opportunities to ask questions of ATC professionals with site visits
  - Qualitative analysis with surface visualizations
  - Quantitative analysis with operational data
- Significant (6-14%) potential benefits from departure metering
  - **BOS**: 900K gallons savings of jet fuel per year
  - **LGA**: Two most frequently-used configurations in VMC alone would yield 550K gallons savings of jet fuel per year, even after accounting for gate-conflicts
  - **PHL**: 2.9M gallons savings of jet fuel per year