Surface Congestion Management

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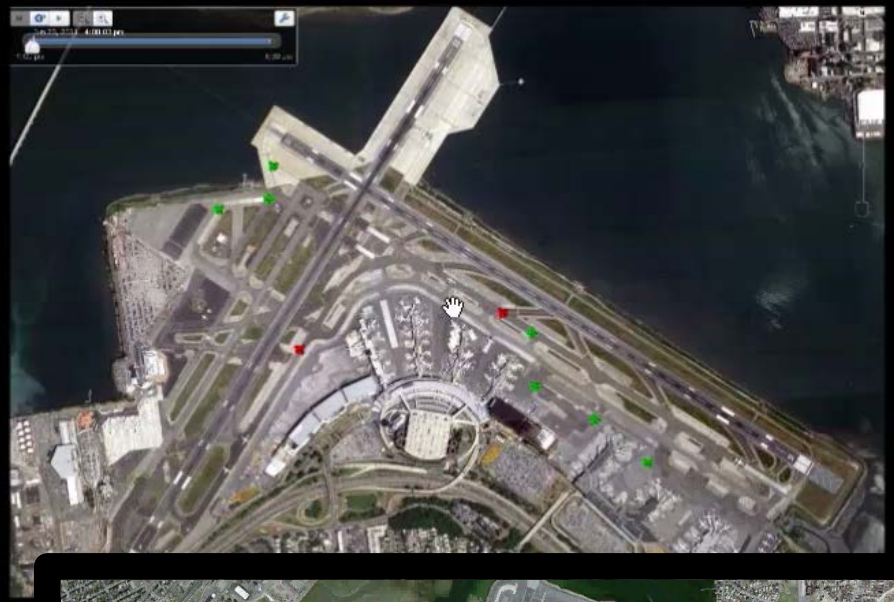
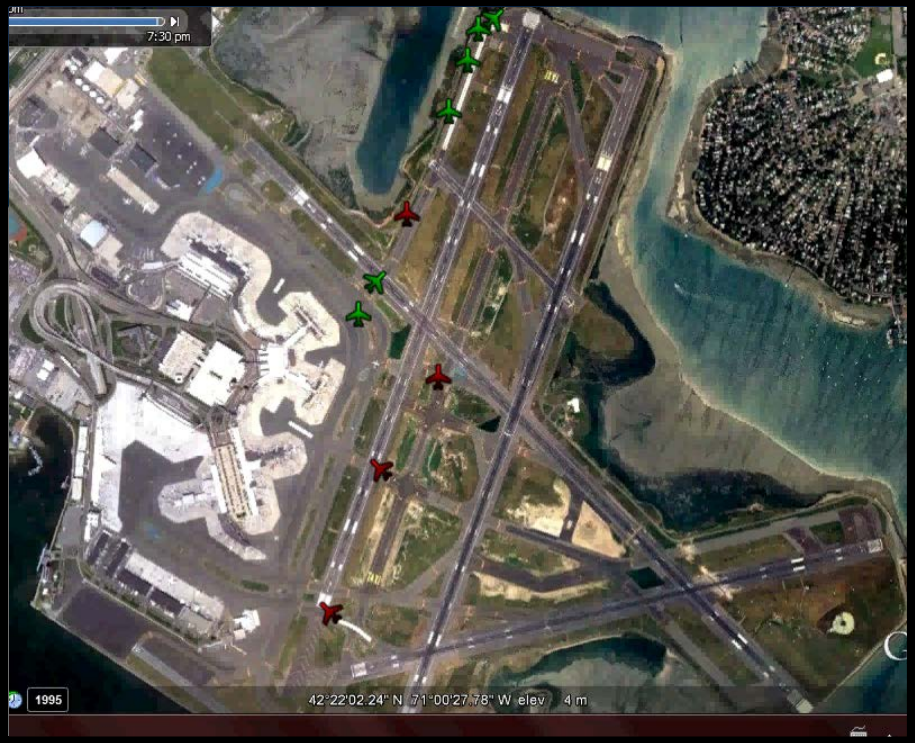
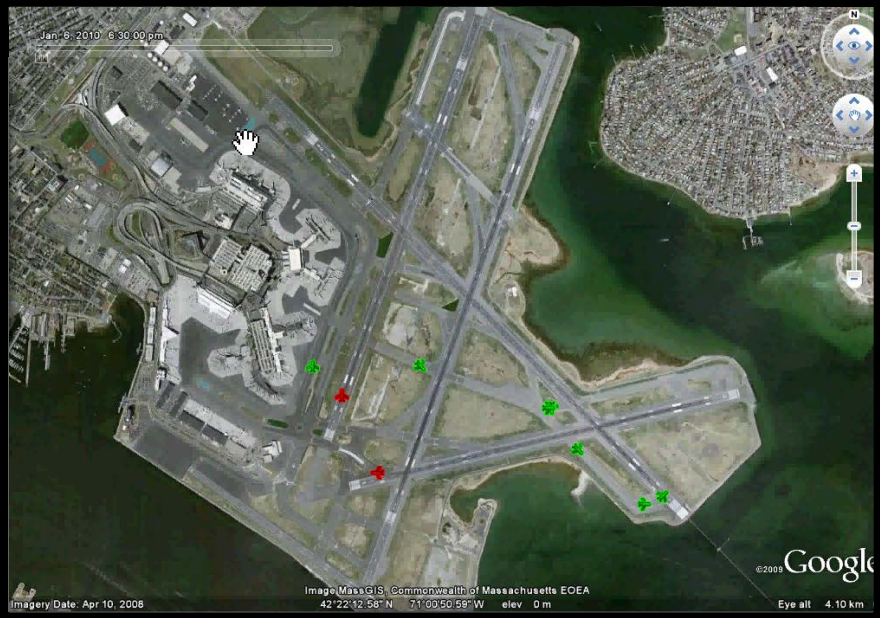
TAM Symposium 2013

Motivation




7:30 pm
1995
42°22'02.24" N 71°00'27.78" W elev 4 m


Jan 8, 2010 6:30:00 pm
Image MassGIS, Commonwealth of Massachusetts EOEA
Imagery Date: Apr 10, 2008
42°22'12.58" N 71°00'50.59" W elev 0 m
Eye alt 4.10 km
©2009 Google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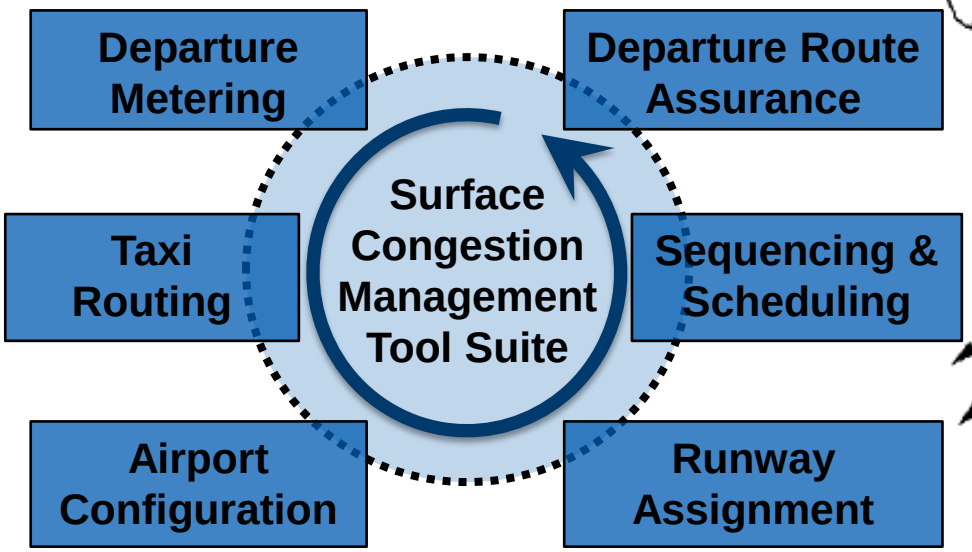
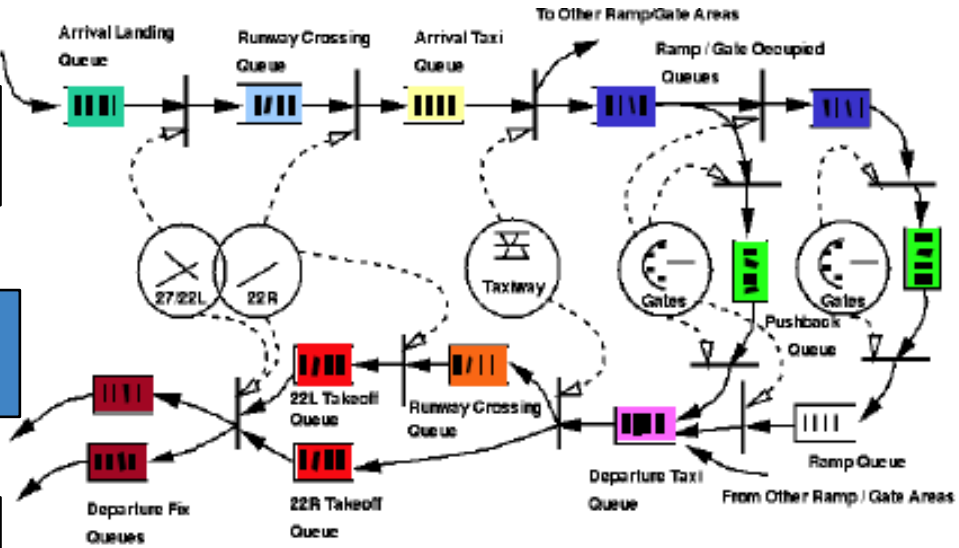
Surface Congestion Management

- Objective: Improve efficiency of airport surface operations
  - Decrease taxi times, decrease fuel burn, improve/maintain airport throughput
- Multiple interconnected, constrained resources: Gates, aprons, taxiways, runways, departure routes, etc.

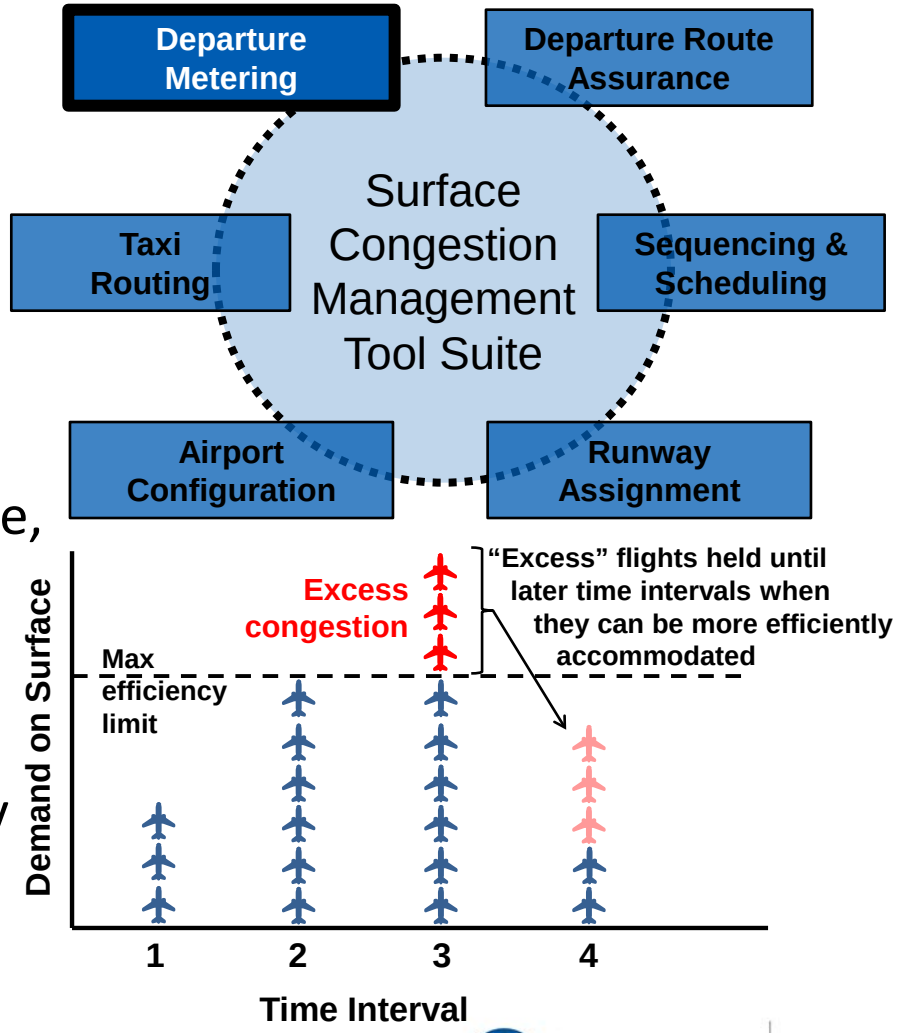




[Idris 2000]

Role of Departure Metering

- Departure metering just one element of required surface management toolset
- Departure metering regulates pushbacks during congested periods
  - Decreased “engines-on” time, fuel burn & emissions
- Principle can work at any congested airport, but implementation details will vary
  - e.g., ATC facility vs. airline ramp tower



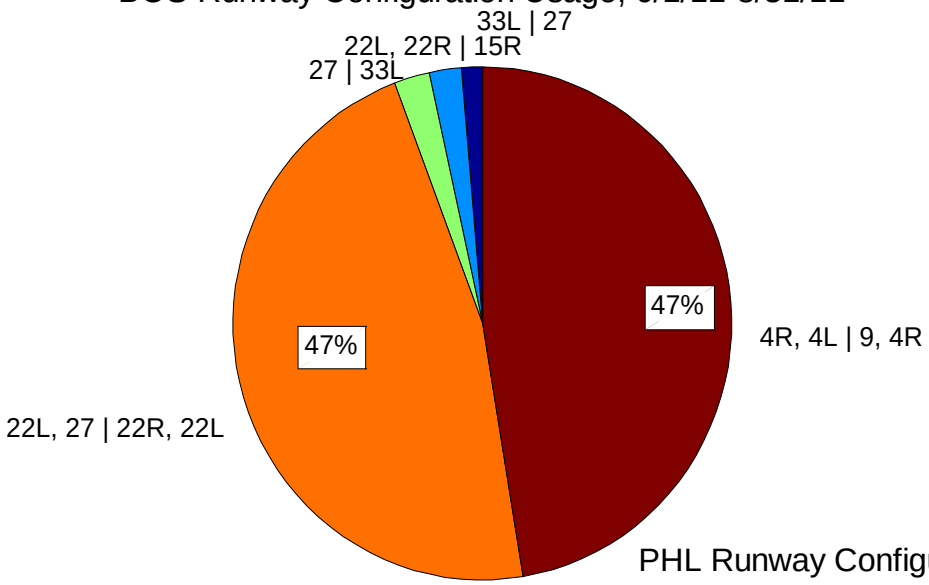
[A. Nakahara, 2012]

Challenges and Opportunities

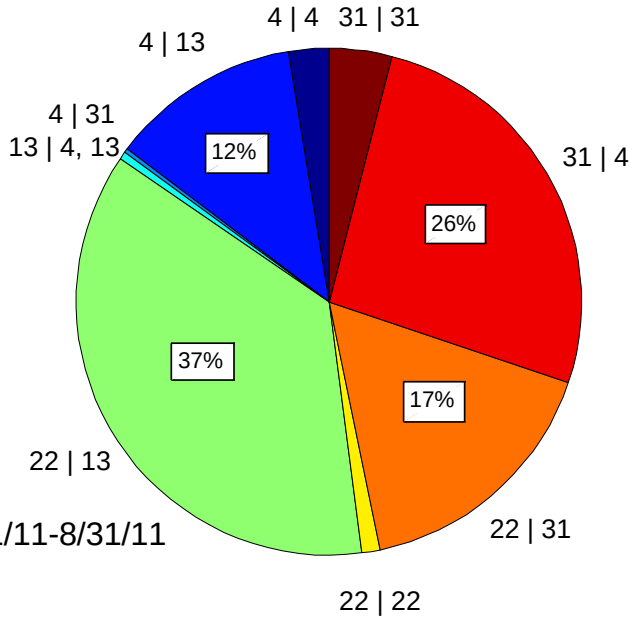
- Uncertainty
  - Weather, runway configuration, demand (pushback/arrival times), operational variability, human factors,…
  - Level of certainty varies depending on information source, type, and time frame
  - What is capacity?
- Level of effort vs. expected benefit
  - Aggregate queue-based control vs. RTA-based trajectory control
  - Information requirements
- Ease of adaptability to different airports and operating environments
- Availability of (diverse) operational data

Operating Environments: Runway Configuration

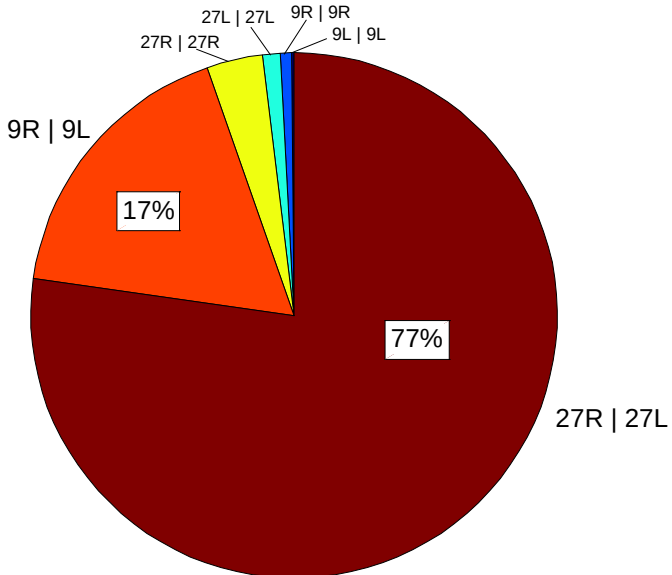
BOS Runway Configuration Usage; 6/1/11-8/31/11



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

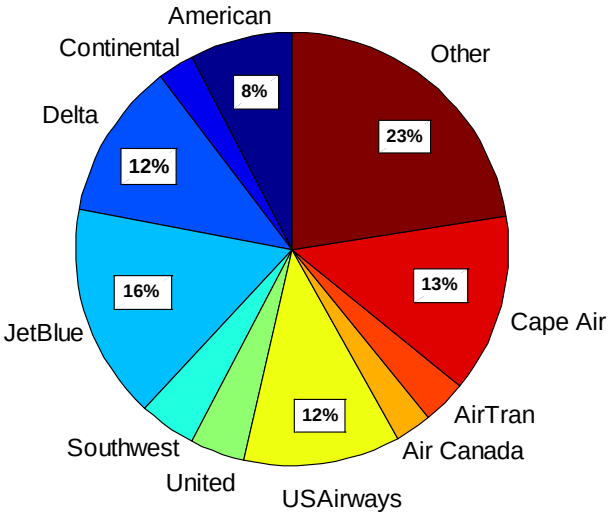


PHL Runway Configuration Usage; 6/1/11-8/31/11

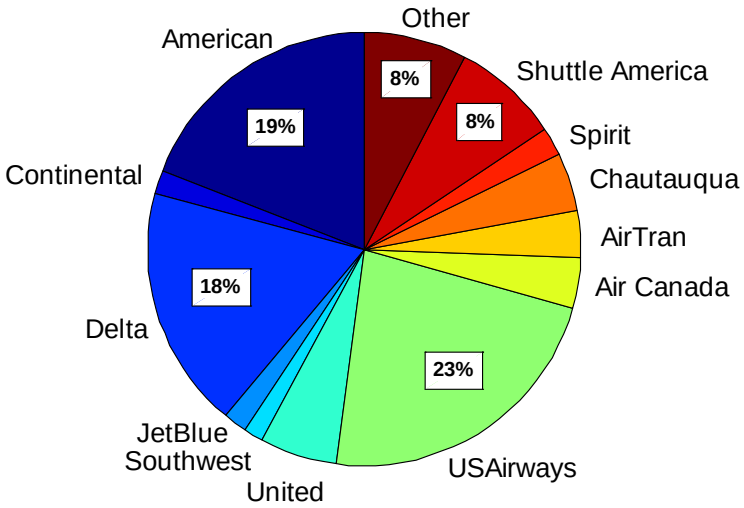


Operating Environments: Airline Mix

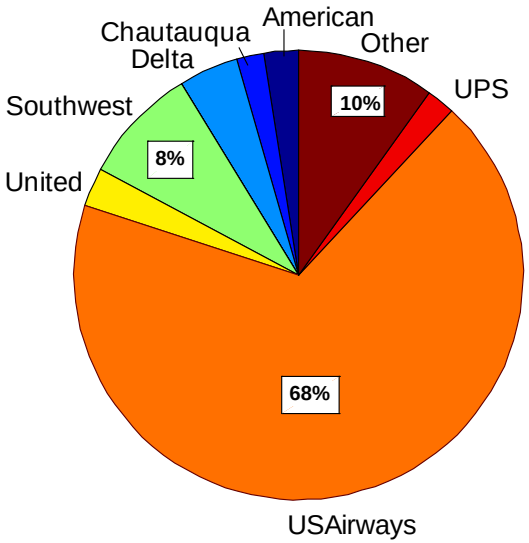
BOS Aircraft Operations by Airline



LGA Aircraft Operations by Airline



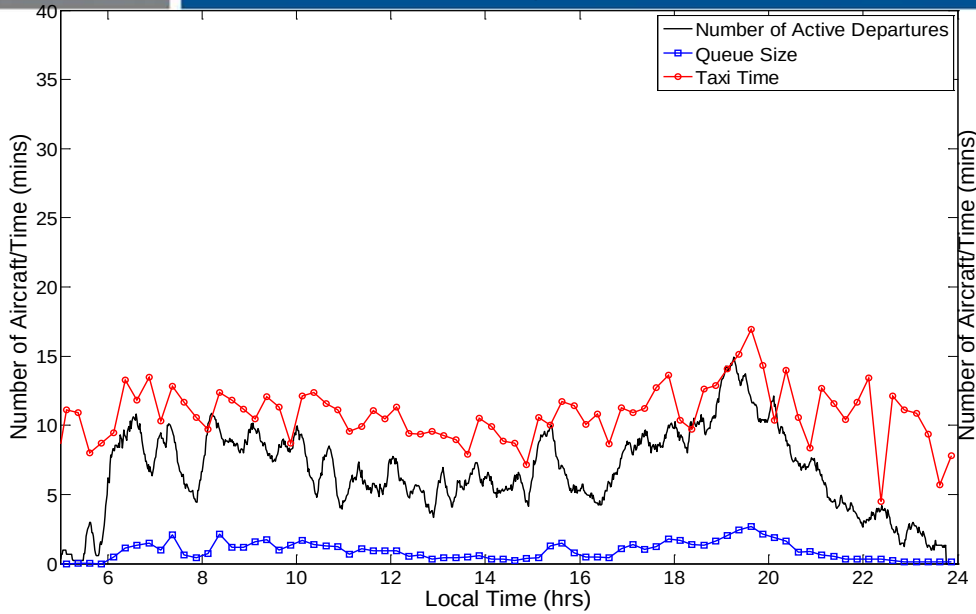
PHL Aircraft Operations by Airline



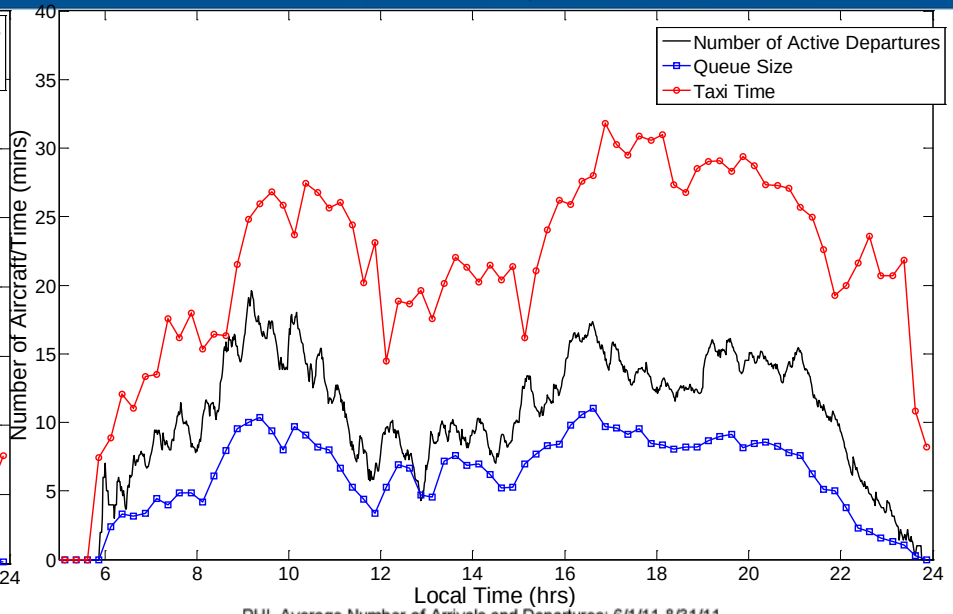
All data from 6/1/11-31/8/11

Operating Environments: Demand Variations

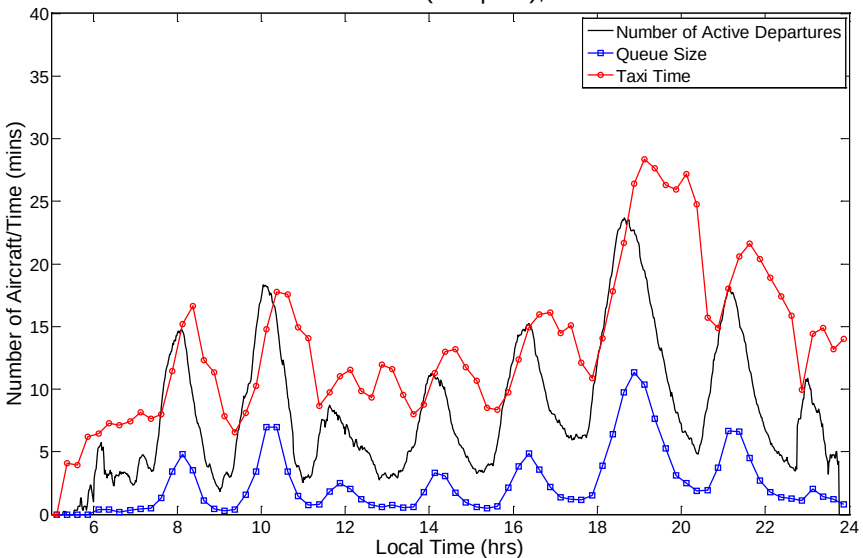
BOS Surface Metrics (22L,27|22R,22L); 6/1/11-8/31/11



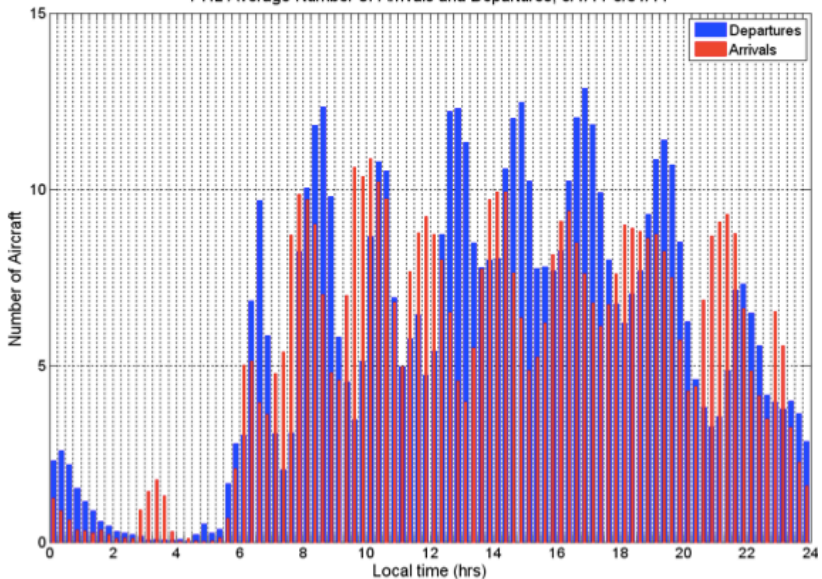
LGA Surface Metrics (22|13); 6/1/11-8/31/11



PHL Surface Metrics (27R|27L); 6/1/11-8/31/11

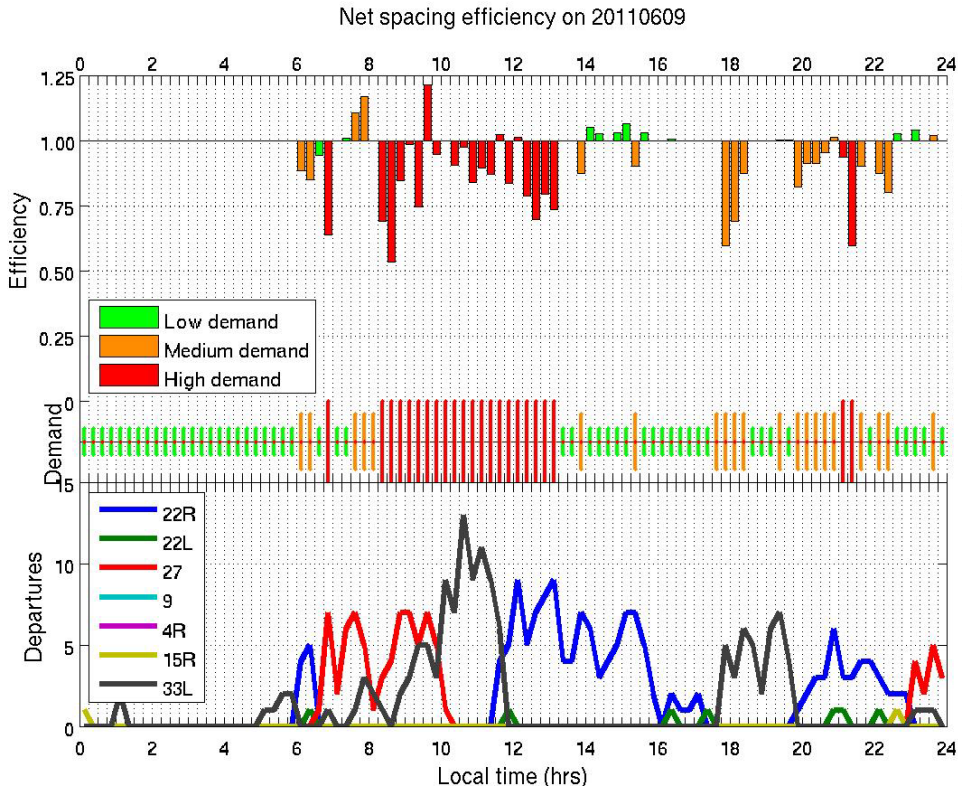


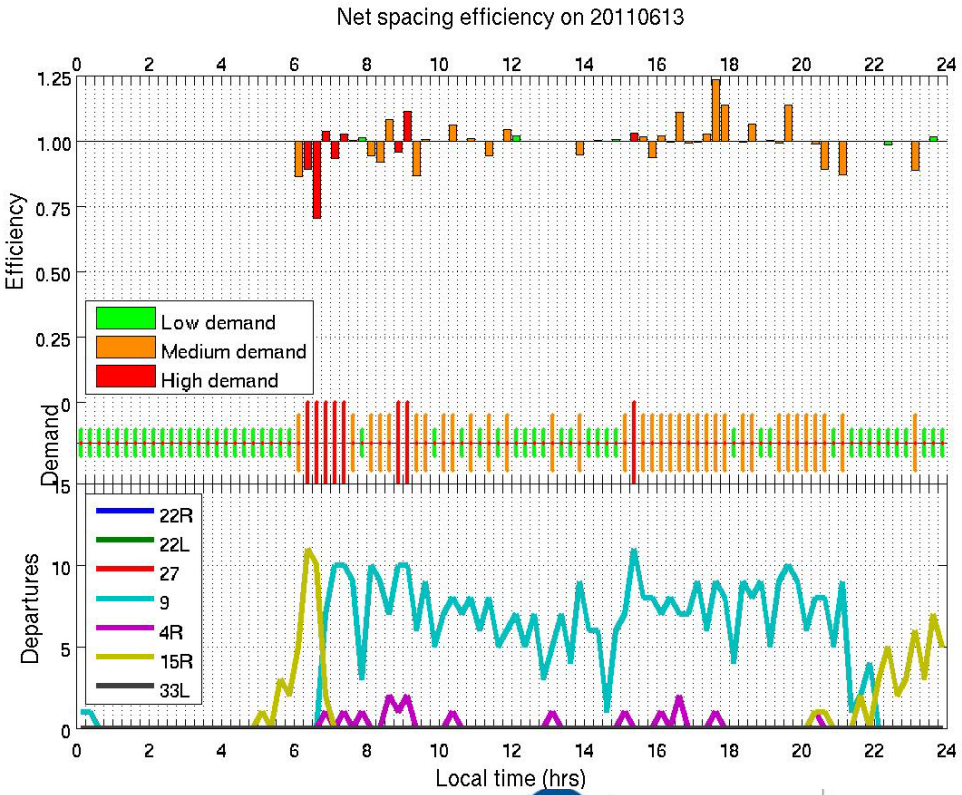
PHL Average Number of Arrivals and Departures; 6/1/11-8/31/11



Airport Operational Efficiency Metrics

- Daily operational efficiency reports to BOS Tower (since Aug 2011)
  - Compare inter-departure separations with target values
  - "Demand level" (combination of departure queue length and number of taxiing departures) for each 15-min interval

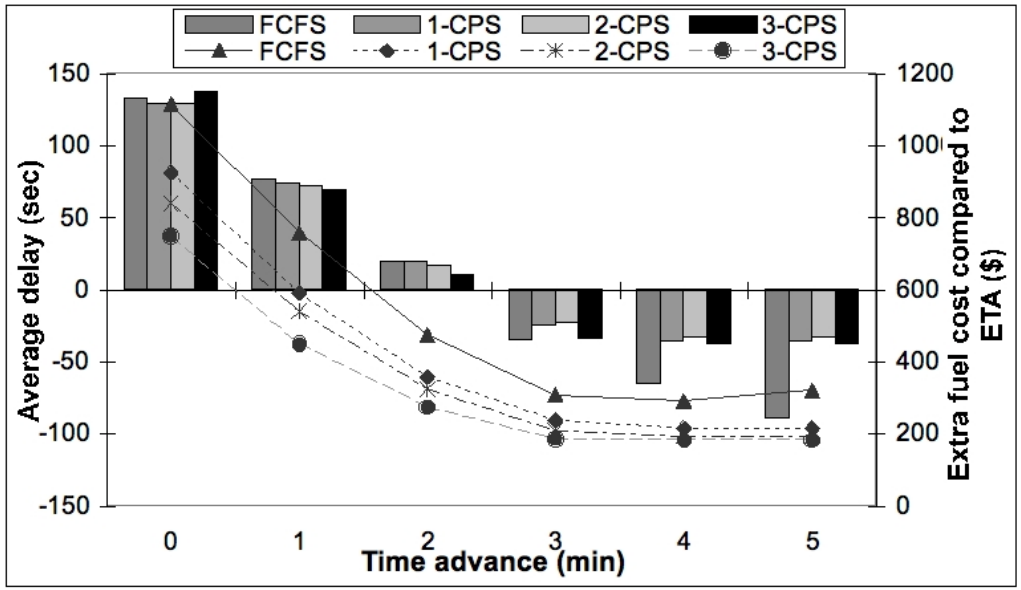




Khadilkar and Balakrishnan, *Air Traffic Control Quarterly*, 2013

Some other projects:
Efficient & Equitable Arrival/Departure Scheduling

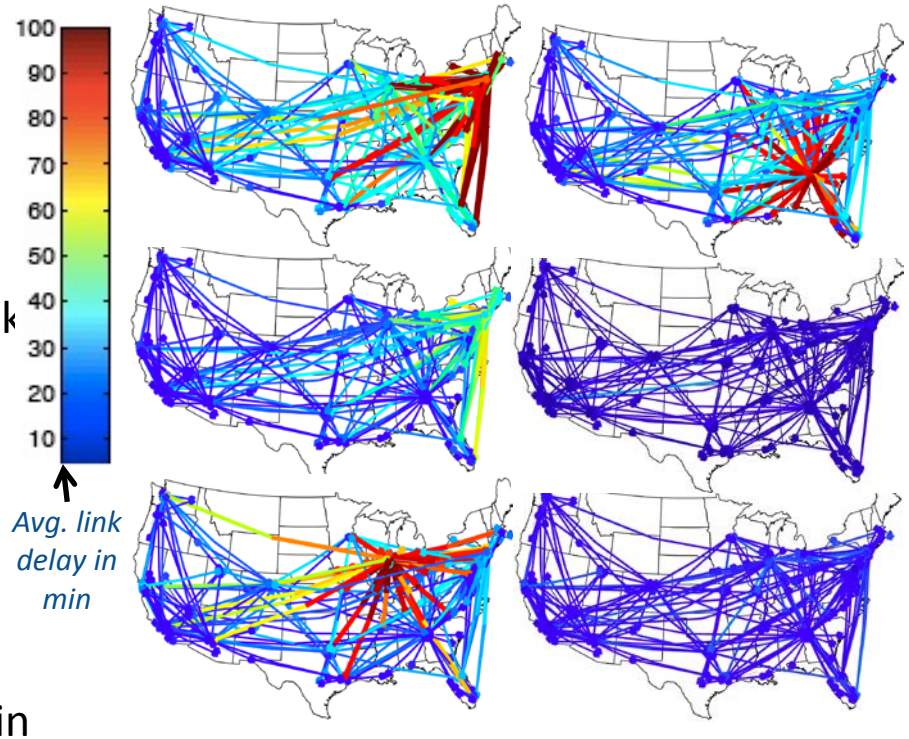
- Given a set of flights with estimated arrival times at the airport, the aircraft need to be sequenced into the landing (takeoff) order, and the landing (takeoff) times need to be determined
  - Need minimum (wt. class dependent) wake vortex separation (Safety)
  - Currently FCFS; resequencing could increase throughput (Efficiency)
  - "Fair" resequencing: Constrained Position Shifting (CPS) [Dear 1976]
- We show that scheduling under constrained position shifting can be solved in (pseudo-)polynomial time as shortest-path problems on variations of this network



Balakrishnan and Chandran, AIAA 2006, ATM R&D Seminar 2007, *Operations Research* 2010
Chandran and Balakrishnan, ACC 2007
Lee and Balakrishnan, ACC 2008, *Proceedings of the IEEE* 2008

Some Other Projects:
Prediction of air traffic delays

- Predict departure delay on a link by considering:
  - Current delay state of the network
  - Interdependencies between network elements
  - Time-of-day and day-of-the-week
  - Delays at origin, destination, and on link
  - Delay state of the National Airspace System (NAS)
  - Type of delay day in the NAS
- Delay states obtained by *k*-means clustering of delays
  - NY, Chicago and Atlanta emerge as main delay centers



Centroids of NAS delay states.
Color represents avg. link departure delay over 2-hr time-window

Rebollo and Balakrishnan, ICRAT 2012

Other Research

- Network modeling and congestion control of airport surface operations
  [Khadilkar and Balakrishnan, *AIAA Journal of Guidance, Control and Dynamics* 2013]
- Mechanisms for resource allocation and reallocation
  [Balakrishnan, Conference on Decision and Control 2007; Ramanujam PhD thesis 2011]
- Discrete-choice models of configuration selection processes
  [Ramanujam and Balakrishnan, American Control Conference 2010]
- Factors influencing pilot penetration of weather
  [Lin and Balakrishnan, *Transportation Research Record* 2014]
- Distributed feedback control of the National Airspace System
  [Le Ny and Balakrishnan, *AIAA Journal of Guidance, Control and Dynamics* 2011]
- Models of engine performance from flight recorder data
  [Khadilkar and Balakrishnan, *Transportation Research Part D* 2012]
- Integration of control and communication algorithms for NextGen
  [Park et al., *IEEE Transactions on Intelligent Transportation Systems* 2013]