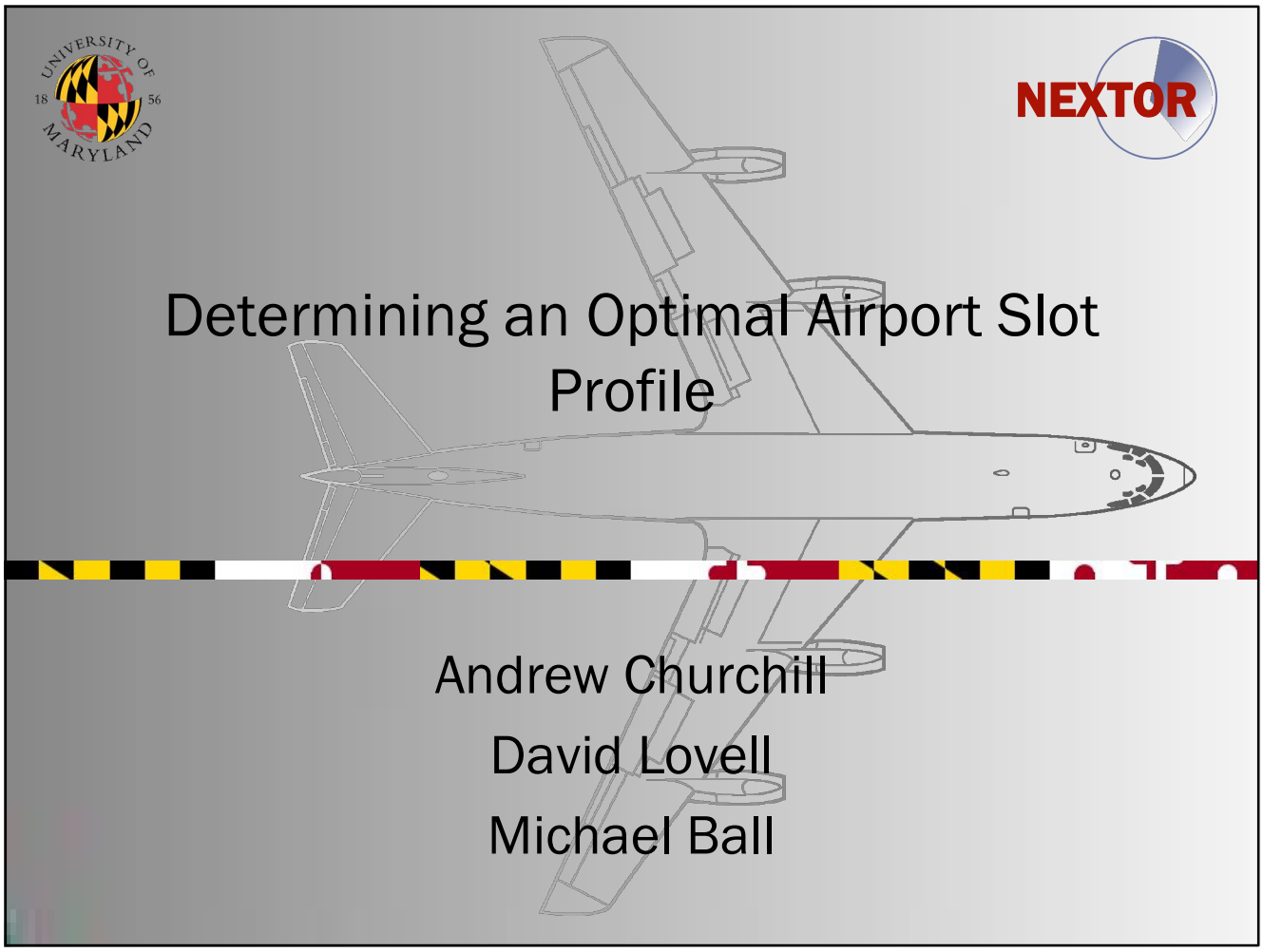
UNIVERSITY OF
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MARYLAND
NEXTOR
Determining an Optimal Airport Slot Profile
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Goals

Problem: *How many* slots should exist in *different time periods* at an airport?

- Examine issues that influence how many slots do/should exist
- Define methodology for determining this number, considering mentioned issues
- Show case study for various scenarios at LaGuardia

Motivation

- Cannot use simple IFR/VFR arrival rates to define number of slots
  - Not really one simple number for either of these conditions
  - Using the “IFR arrival rate” would leave the airport underutilized most of the time
  - Using the “VFR arrival rate” would leave the airport very congested during marginal or worse conditions
- Need to define some criteria for finding a middle ground

Level of Service

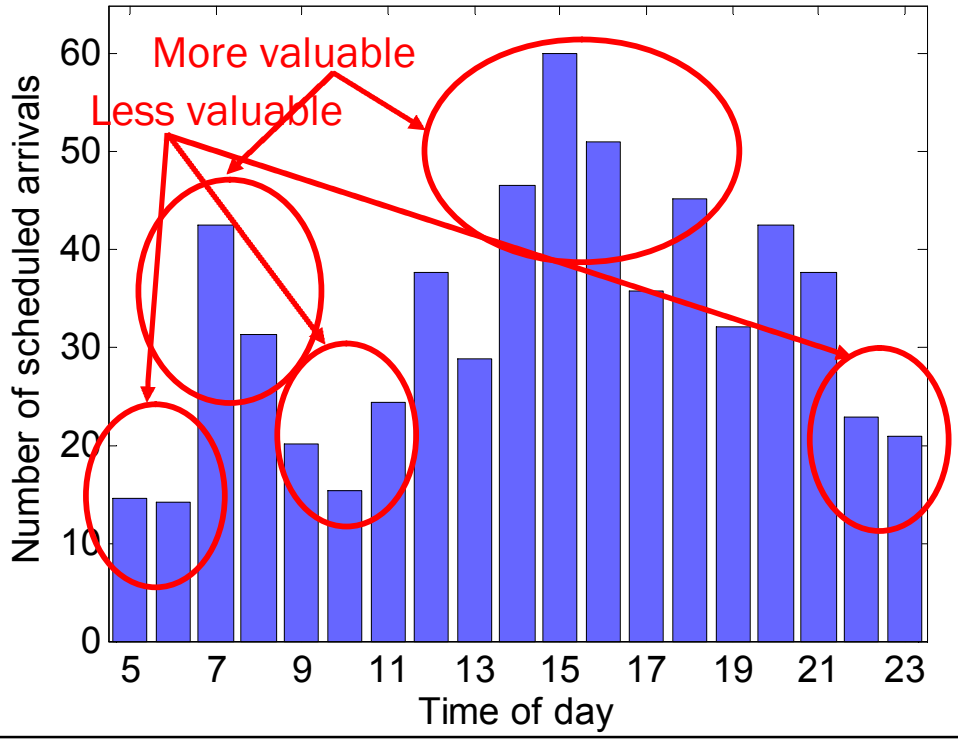
- Measure delays and cancellations
  - Must balance these metrics against number of slots available
- Number of slots closer to airport capacity results in more delays and cancellations
- Airlines have the ability to make a tradeoff between delays and cancellations

Scheduling Value Trends

- Some time periods are naturally more valuable to travelers/airlines
  - Scheduling – e.g. arrive before daylong meeting
  - Geography – e.g. oceanic/transcontinental traffic
- Airlines know this – examine scheduling trends

Scheduling Value Trends

- JFK, July 16-20, 2007 (averaged weekdays)



From ASPM

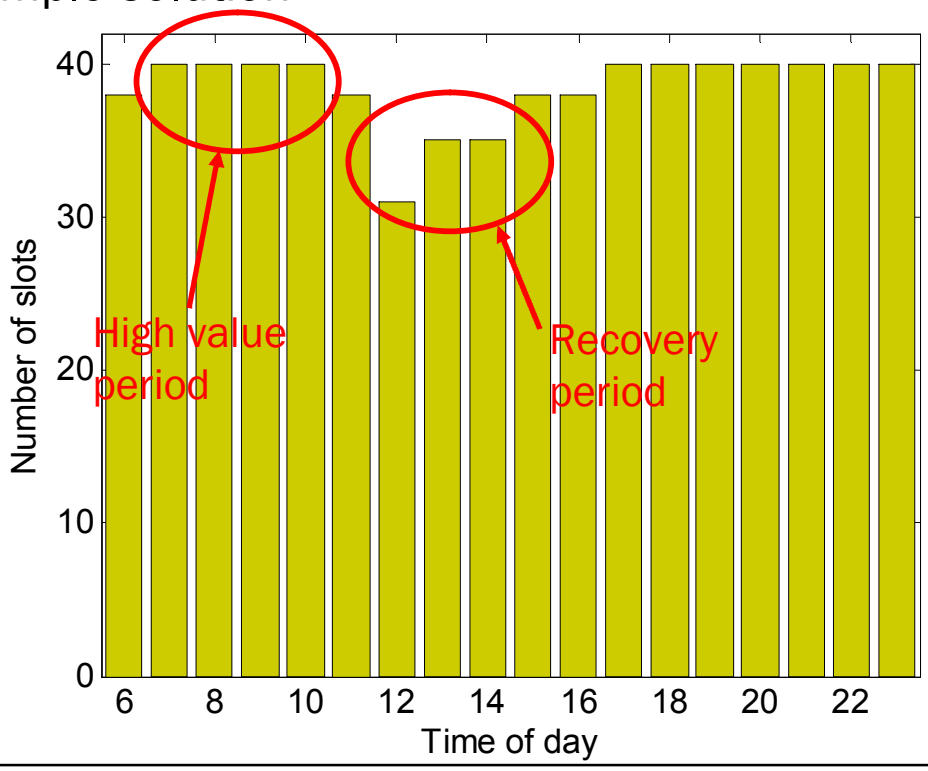
Recovery Periods

- Well known that an airport cannot operate at "peak" capacity during every hour of every day

- Schedule to peak capacity during most desirable parts of the day
- Schedule to lower levels during less desirable parts of the day to "recover" from earlier delays
  - Earlier delay is most costly than later delay, as it can propagate further through the NAS

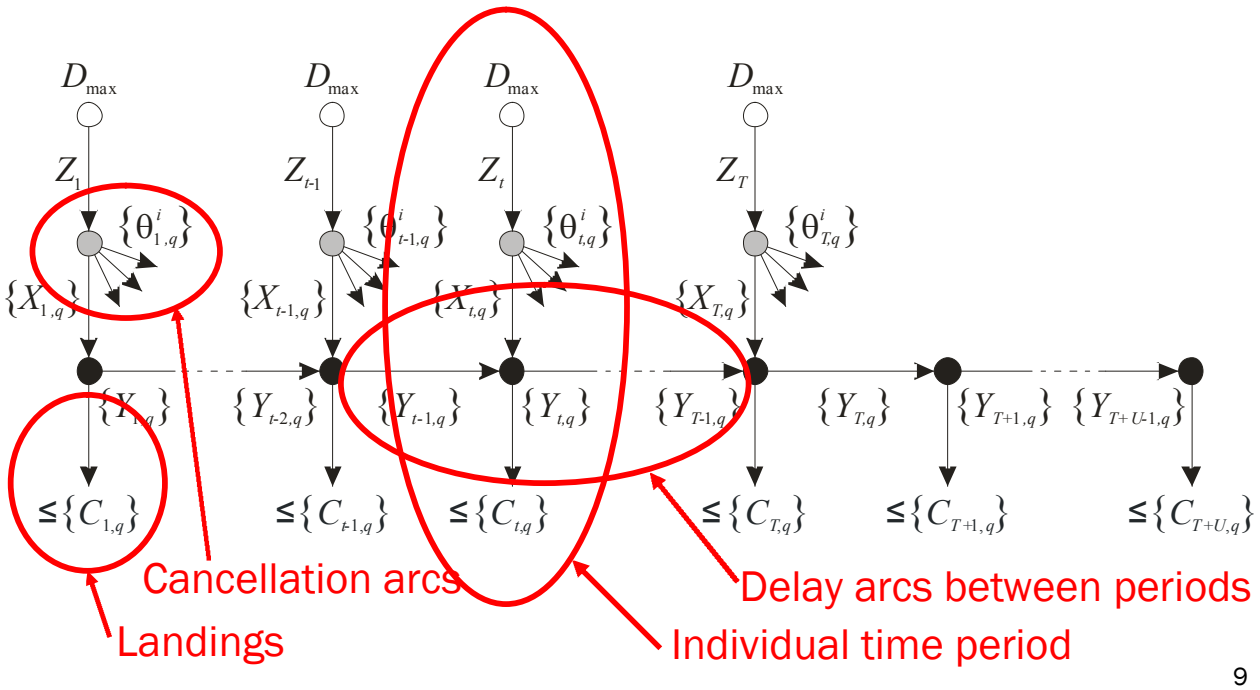
Recovery Periods

- Example solution



Approach

- Linear programming network flow approach

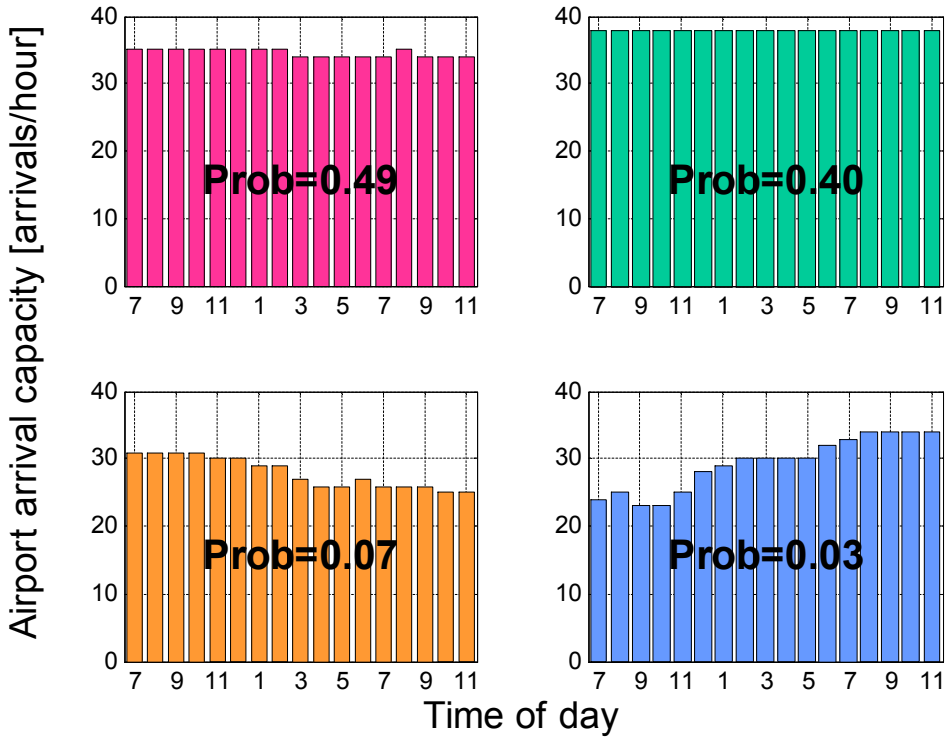


Assumptions

- Determine only the number of arrival **or** departure slots
  - The other will necessarily follow
- Number of slots in each time period constrained by upper/lower bounds
  - Allows for non-uniform slot profile
- Maximum delay length constrained
- Optimize across spectrum of capacity scenarios

Capacity Scenarios

- Data from LGA 2003



From (Barry Liu, Mark Hansen 2005)

Assumptions

- Determine only the number of arrival **or** departure slots
  - The other will necessarily follow
- Number of slots in each time period constrained by upper/lower bounds
  - Allows for non-uniform slot profile
- Maximum delay length constrained
- Optimize across spectrum of capacity scenarios
- All slots in time period have same “value”

Slot “Values”

- NEXTOR conducted congestion pricing strategic simulation for LGA (2004)
  - Ranged from $100 - $1200
- We use these prices to represent slot values in each time period

Mathematical Modeling Approach

- Objective: Maximize total value of slots
- Deterministic queuing delay model
- Basic cancellation prediction model
- Specified delay and cancellation levels

$$\max\left\{\sum_t V_t Z_t\right\}$$

Subject to

$Z_t - X_{t,q} - \sum_i \theta_{t,q}^{\ i} = 0$	$\forall t \in \{1,\ldots,T\},\ q \in \{1,\ldots,Q\}$
$X_{1,q} - Y_{1,q} \le C_{1,q}$	$\forall q \in \{1,\ldots,Q\}$
$X_{t,q} + Y_{t-1,q} - Y_{t,q} \le C_{t,q}$	$\forall t \in \{2,\ldots,T\},\ q \in \{1,\ldots,Q\}$
$Y_{t-1,q} - Y_{t,q} \le C_{t,q}$	$\forall t \in \{T+1,\ldots,T+U-1\},\ q \in \{1,\ldots,Q\}$
$Y_{T+U-1,q} \le C_{T+U,q}$	$\forall q \in \{1,\ldots,Q\}$
$D_{\min} \le Z_t \le D_{\max}$	$\forall t \in \{1,\ldots,T\}$
$Y_{t,q} \le W_{t,q}$	$\forall t \in \{1,\ldots,T+U-1\},\ q \in \{1,\ldots,Q\}$
$\theta_{t,q}^{\ i} \le P_i$	$\forall t \in \{1,\ldots,T\},\ q \in \{1,\ldots,Q\},\ i \in \{1,\ldots,N\}$
$X_{t,q}, Y_{t,q}, Z_t, \theta_{t,q}^{\ i} \in \mathbb{N}^+$	$\forall t \in \{1,\ldots,T\},\ q \in \{1,\ldots,Q\},\ i \in \{1,\ldots,N\}$
$\sum_q p_q \sum_t Y_{t,q} - \gamma \sum_t Z_t \le 0$	
$\sum_q p_q \sum_i \sum_t \theta_{t,q}^{i} - \rho \sum_t Z_t \le 0$	

Where

$W_{t,q} = \sum_{i=t+1}^{\min\{t+U,T+U\}} C_{i,q}$	$\forall t \in \{1,\ldots,T+U-1\},\ q \in \{1,\ldots,Q\}$

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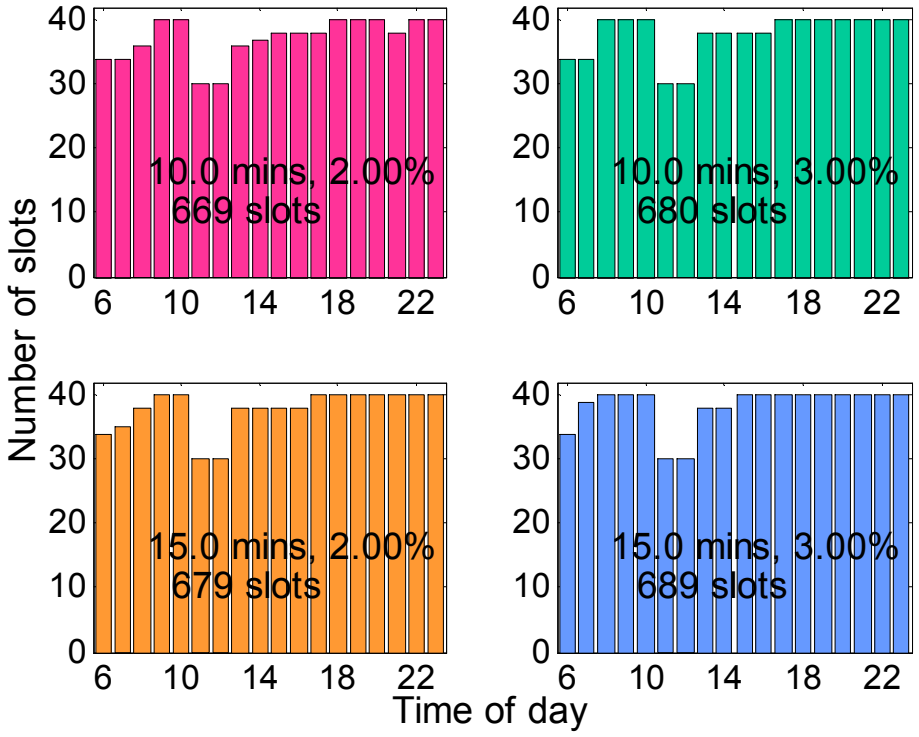
Results with Variable Profile

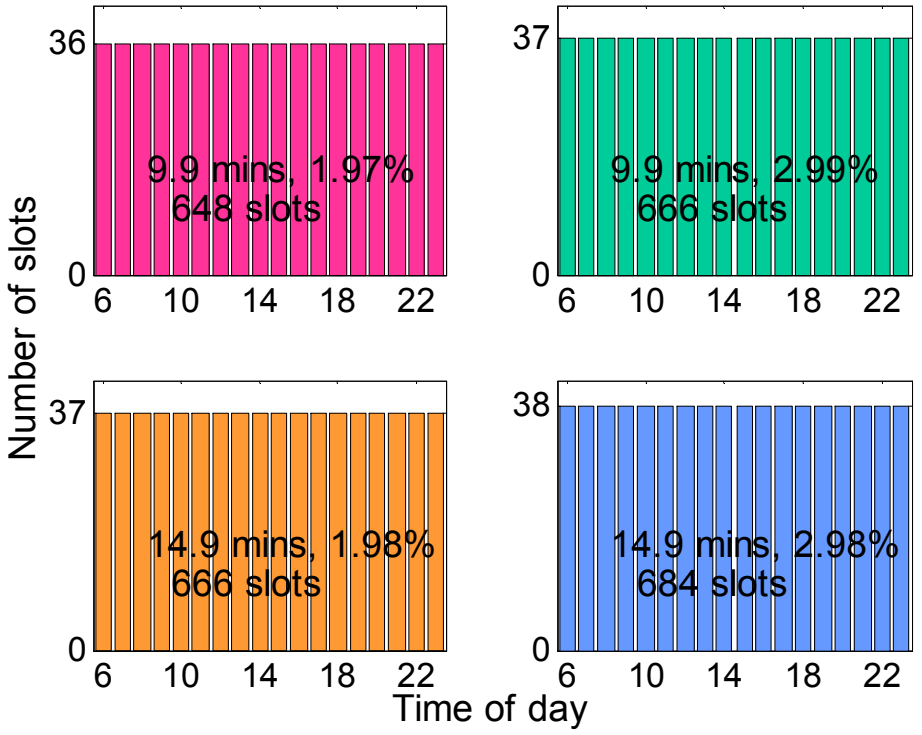
- LaGuardia, using inputs shown earlier



Non-uniform slot profiles permitted

Results with Constant Profile

- LaGuardia, using inputs shown earlier



Uniform slot profiles required

Comparison of Variable and Uniform

- Difference in overall value of slots created

-5.83%	-4.93%
-4.74%	-3.66%

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Continuing Work

- Develop criteria for determining to which airports such a procedure is applied
- Consider other factors that influence when to schedule operations (i.e. more than slot value)
- Change weighting used for each capacity scenario