Modeling Delays and Cancellation Probabilities to Support Strategic Simulations

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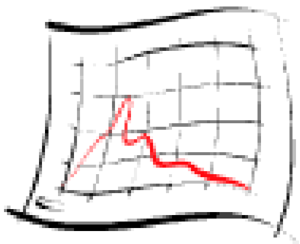
Outline

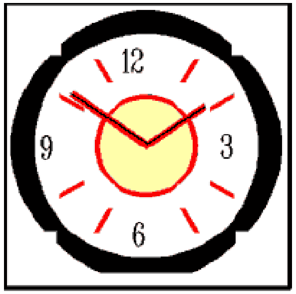
I. Strategic simulations

II. Capacity scenarios



III. Cancellation model

IV. Delay model



V. Applications

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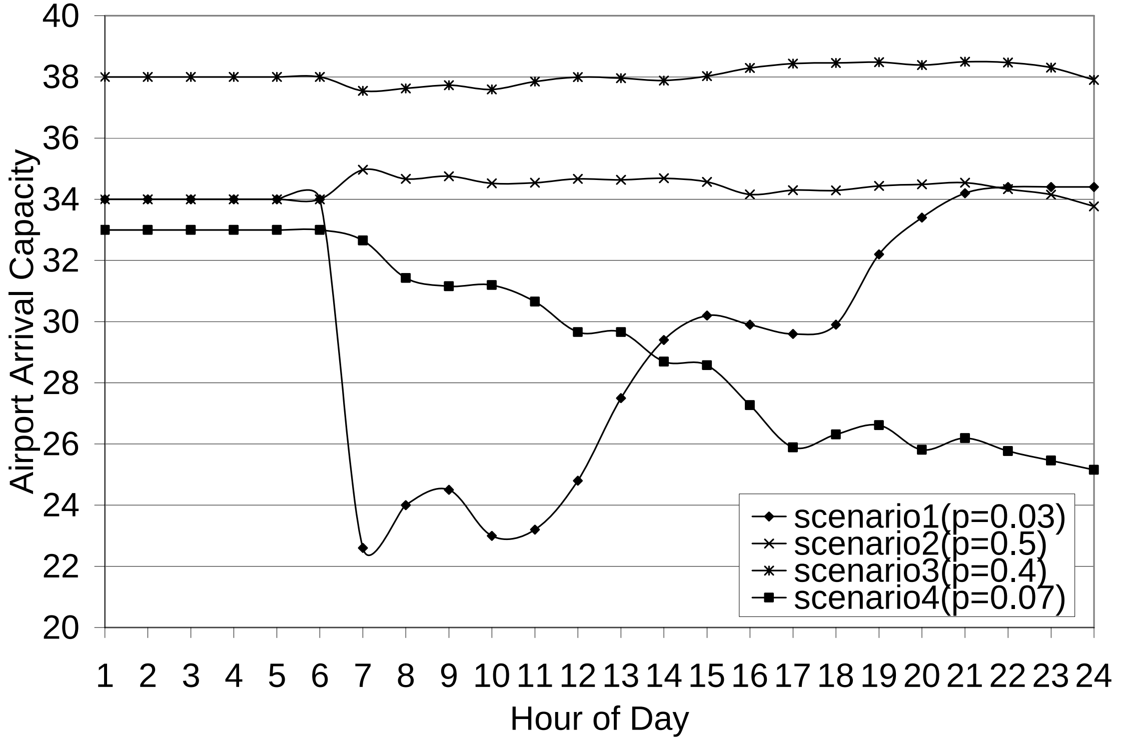
Strategic simulations

- 2 exercises so far to study market mechanisms at LaGuardia and other airports
- Congested schedules → delays and cancellations → monetary costs to airlines (PBR) → schedule revisions
- Airline participation, fast response time, 3-month study interval and dearth of information → aggregate models based only on observational data

Capacity scenarios

- Cluster analysis of AARs from all of 2003
- Work done by Hansen et al. at Berkeley

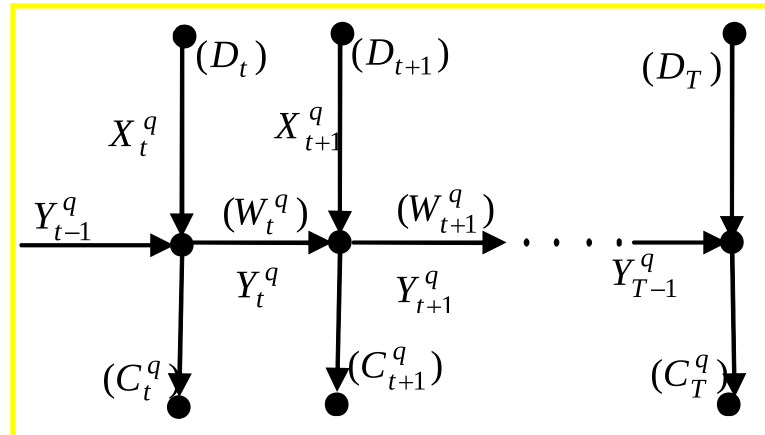


Cancellation model

- Hypothetical model: cancellation rates can be predicted in the aggregate by estimating the schedule reduction necessary to keep delay below some threshold
- For this purpose, delay is estimated using a simple deterministic model cast as a maximum network flow problem
- Calibration via known schedules, AARs, and cancellations from ASPM data

Maximum network flow model

- Demand D_t
- Capacity C_t^q
- Maximum delay U
- Transfer capacity $W_t^q = \sum_{t+1}^{t+U} C_t^q$
- Decision variables:
  - Throughput X_t^q
  - Postponed demand Y_t^q
- Optimization problem: max $\sum_t X_t^q$



s.t. $0 \le X_t^q \le D_t \qquad 0 \le Y_t^q \le W_t^q$

$$0 \le X_t^q + Y_{t-1}^q - Y_t^q \le C_t^q \qquad t \in \{1,..,T\}, q \in \{1,..,Q\}$$

Model outputs

- Scenario-specific cancellation probability

$$P_{\text{cnx}}^{q} = \frac{\sum_{t=1}^{24}(D_t - X_t^q)}{\sum_{t=1}^{24} D_t}$$

- Overall cancellation probability

$$\sum_{q=1}^{Q}\left(P^q\right)\left(P_{\text{cnx}}^{q}\right)$$

- Incorporate ambient cancellation rate

$$P_{\text{cnx}} = 0.03 + \sum_{q=1}^{Q}\left(P^q\right)\left(P_{\text{cnx}}^{q}\right)$$

Delay model

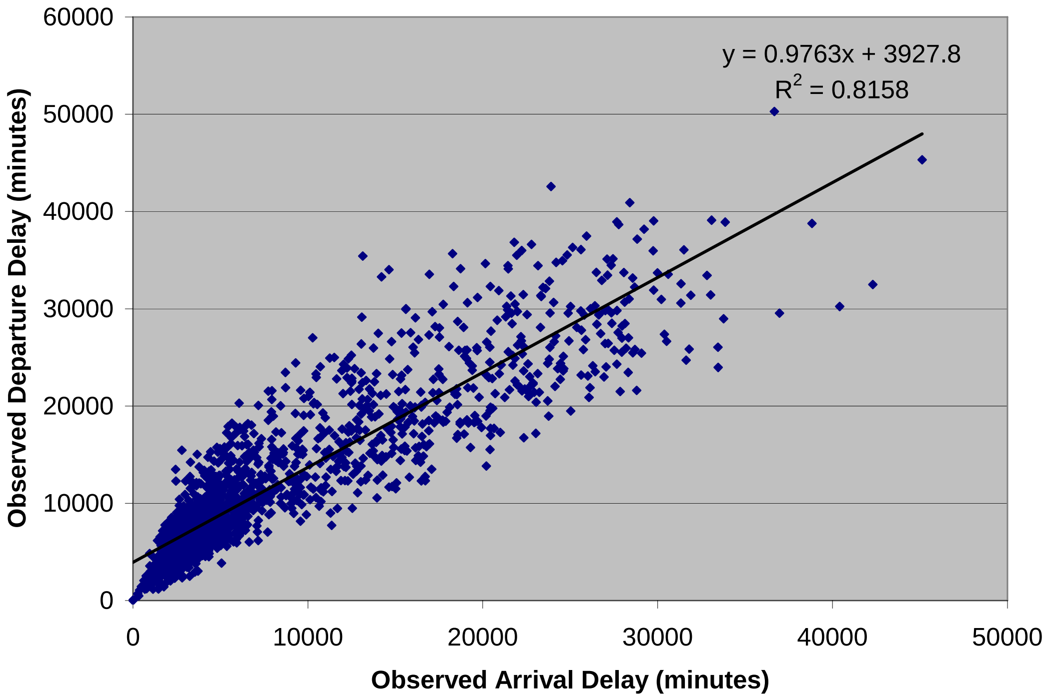
- Model the aircraft arrival process as a non-homogeneous Poisson process with Erlang-r service times (DELAYS© code, developed at MIT by Koopman, Kivestu, Malone)
- Stochastic model produces pdf's for relevant outputs
- We used conditionally on each capacity scenario and then took expectations
- Output of interest was % of flights with delays over 15 minutes

Applications

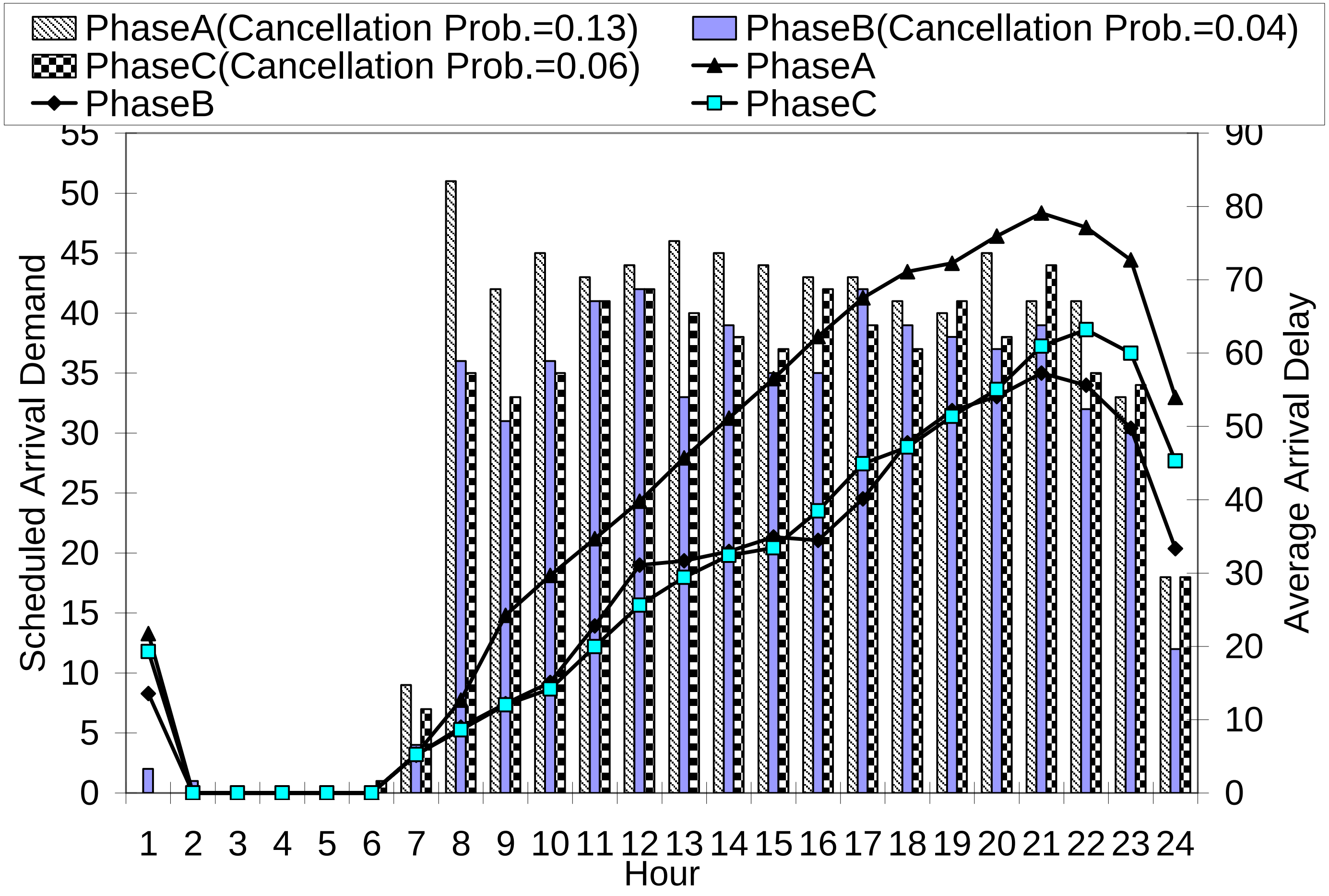
- Strategic simulation
  - Passenger Bill of Rights (PBR)
  - Impose monetary costs for cancellations ($\$C_c$) and delays over 15 minutes ($\$C_d$)
- Slot auction
  - Determine the appropriate number of slots in each hour
  - Slot values were estimated from congestion pricing results in strategic simulation
  - Maximize the total value of slots offered, subject to constraints on delays and cancellations

Departure delays

- Only arrival delays were modeled as a queueing system – departure delays were estimated with regression



Strategic simulation results



Number of slots to offer

- LP model based on previous cancellation model, but with additional side constraints:
  - UB η on cancellation probability

$$\sum_{q=1}^{Q} P^q \sum_{t=1}^{24} (D_t - X_t^q) - \eta \sum_{t=1}^{24} D_t \leq 0$$

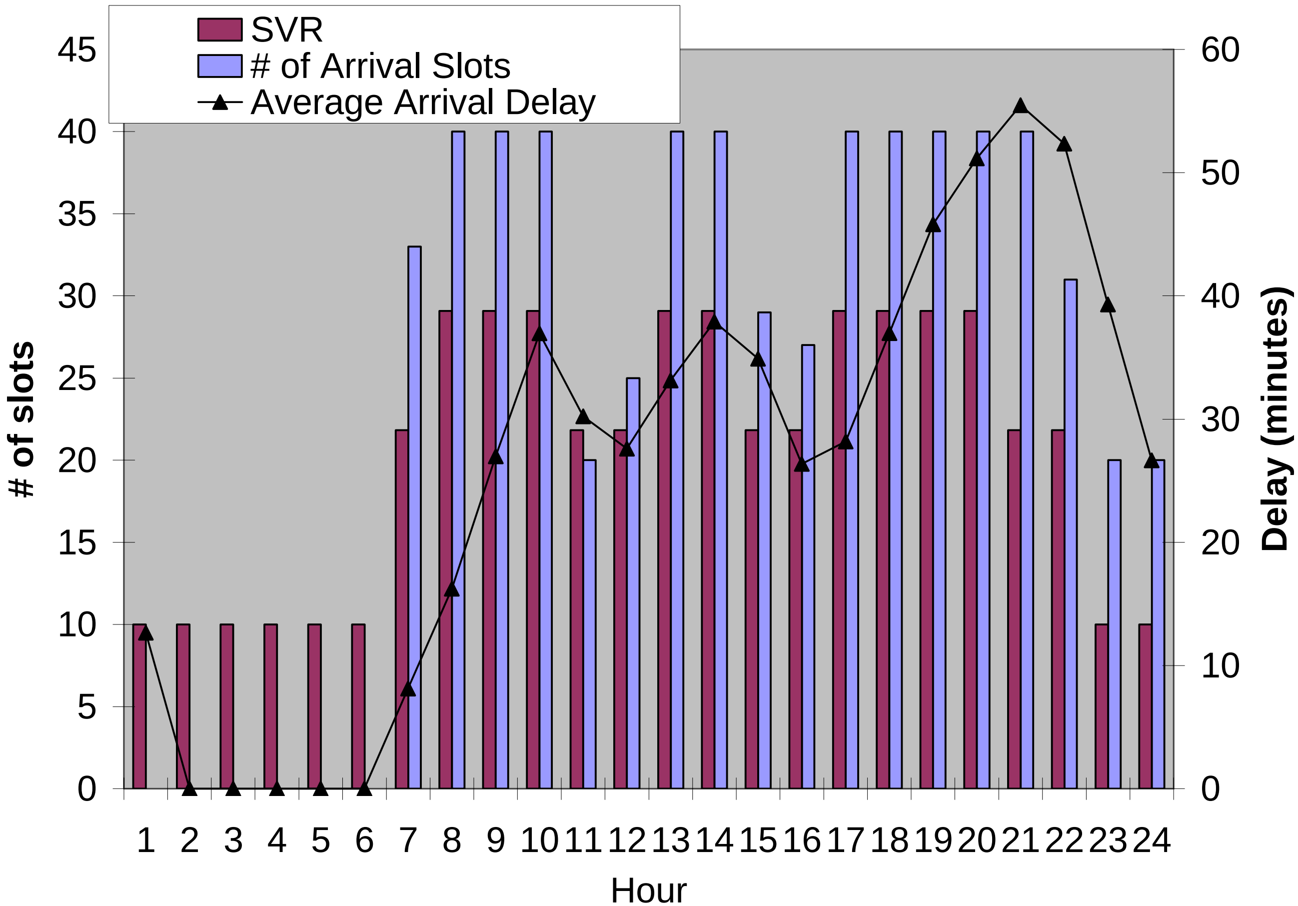
  - UB μ on delay

$$\sum_{q=1}^{Q} P^q \sum_{t=1}^{24} Y_t^q - \mu \sum_{t=1}^{24} D_t \leq 0$$

  - Min and max numbers of slots

$$D_{\min} \leq D_t \leq D_{\max}$$

Slot offering results



Conclusions

- Simple and expedient models
- Useful for iterative strategic planning exercises with multiple airlines:
  - Low levels of airline-specific competitive and/or proprietary information
  - Fast run times (on the order of seconds) to facilitate multiple scenarios and quick response
- Useful for setting preliminary values of parameters for new resource allocation regimes without a strong economic history