FAA NEXTOR NAS Performance Workshop, Asilomar, 4/14/2009

Analyzing Aircraft Taxi Times at Airports: Comparison and Decomposition

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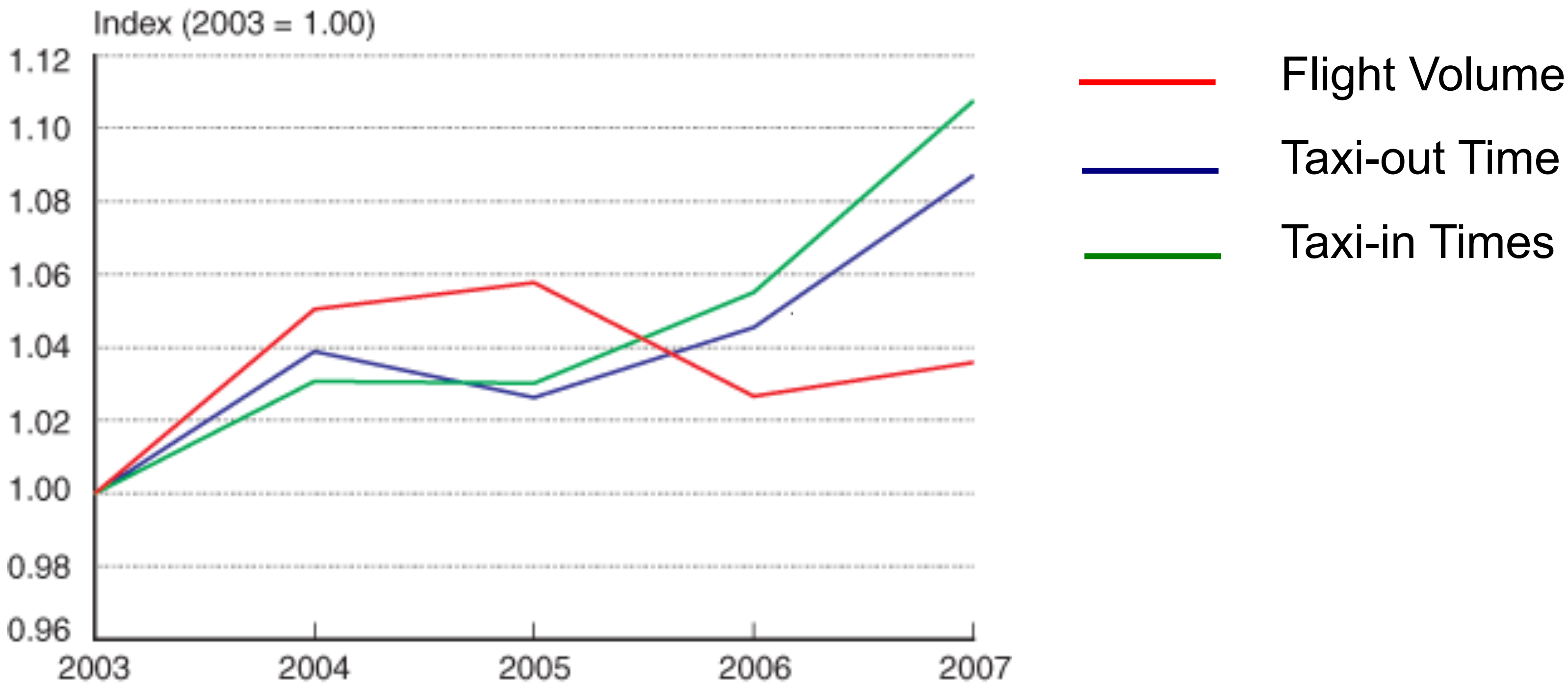
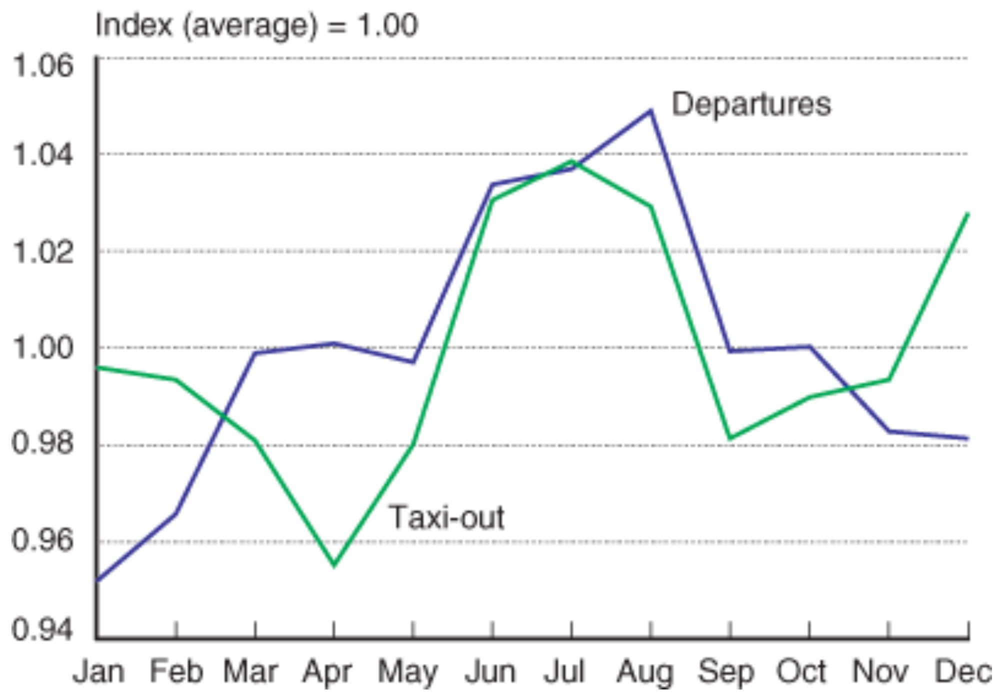
BTS Report (1)


Index (2003 = 1.00)
1.12
1.10
1.08
1.06
1.04
1.02
1.00
0.98
0.96
2003
2004
2005
2006
2007
Flight Volume
Taxi-out Time
Taxi-in Times

BTS Report (2)



Index (average) = 1.00
1.06
1.04
1.02
1.00
0.98
0.96
0.94
Departures
Taxi-out
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Roadmap

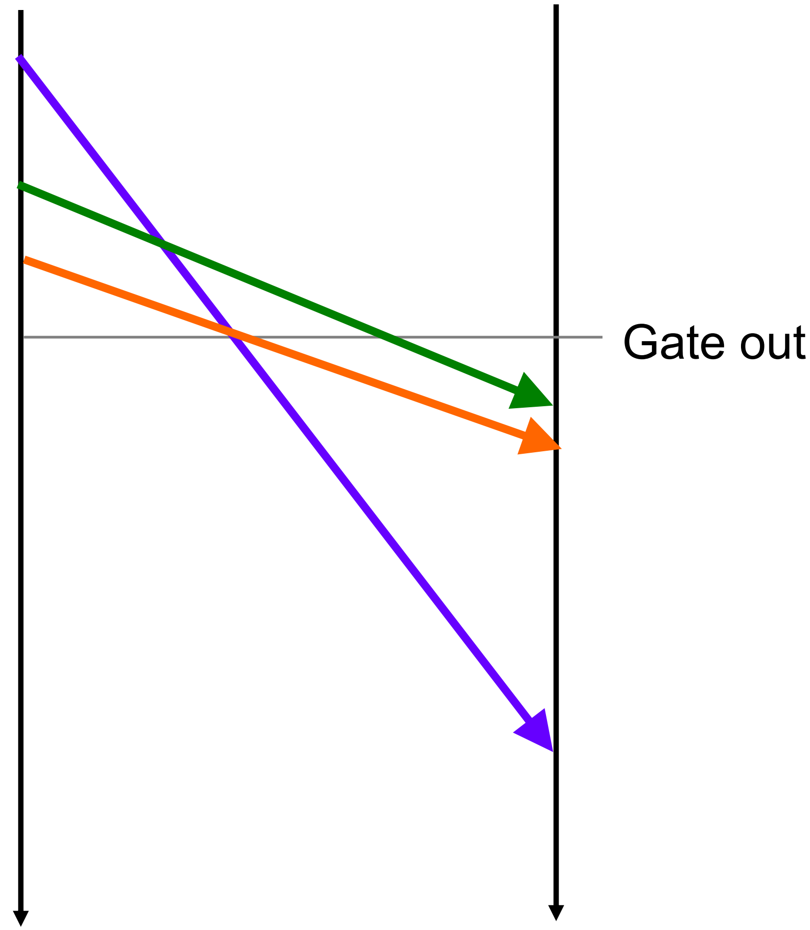
- Review and compare taxiing time models
  - Existing model
  - Alternative model
- Decompose taxiing time
  - Taxi time according to scheduling
  - Excess taxi time
- Work in-progress
  - Integrated Model for Departure Sequence and Gate Push-back Times
  - Impact of Airport Delay on National System

Causal Factors Affecting Taxi Times

- Arrival and departure demands
- Arrival and departure queue lengths
- Runway configuration
- Airline/terminal
- Weather and upstream and downstream restrictions
- Other factors

Exiting Model

- Group: Origin-Destination, Carrier, Season
- Excluding the upper 25% taxiing time in estimation
- Departure queue length: the number of aircraft ahead of the flight at the queue entry time (gate out time)
- Arrival queue length: the number of aircraft ahead of the flight at the queue entry time (wheel-on time).



Exiting Model

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- Departure queue length: the number of aircraft ahead of the flight at the queue entry time (gate out time)
- Arrival queue length: the number of aircraft ahead of the flight at the queue entry time (wheel-on time).

Regression model:

$$y_o = a \cdot x_o + b \cdot x_i + c$$

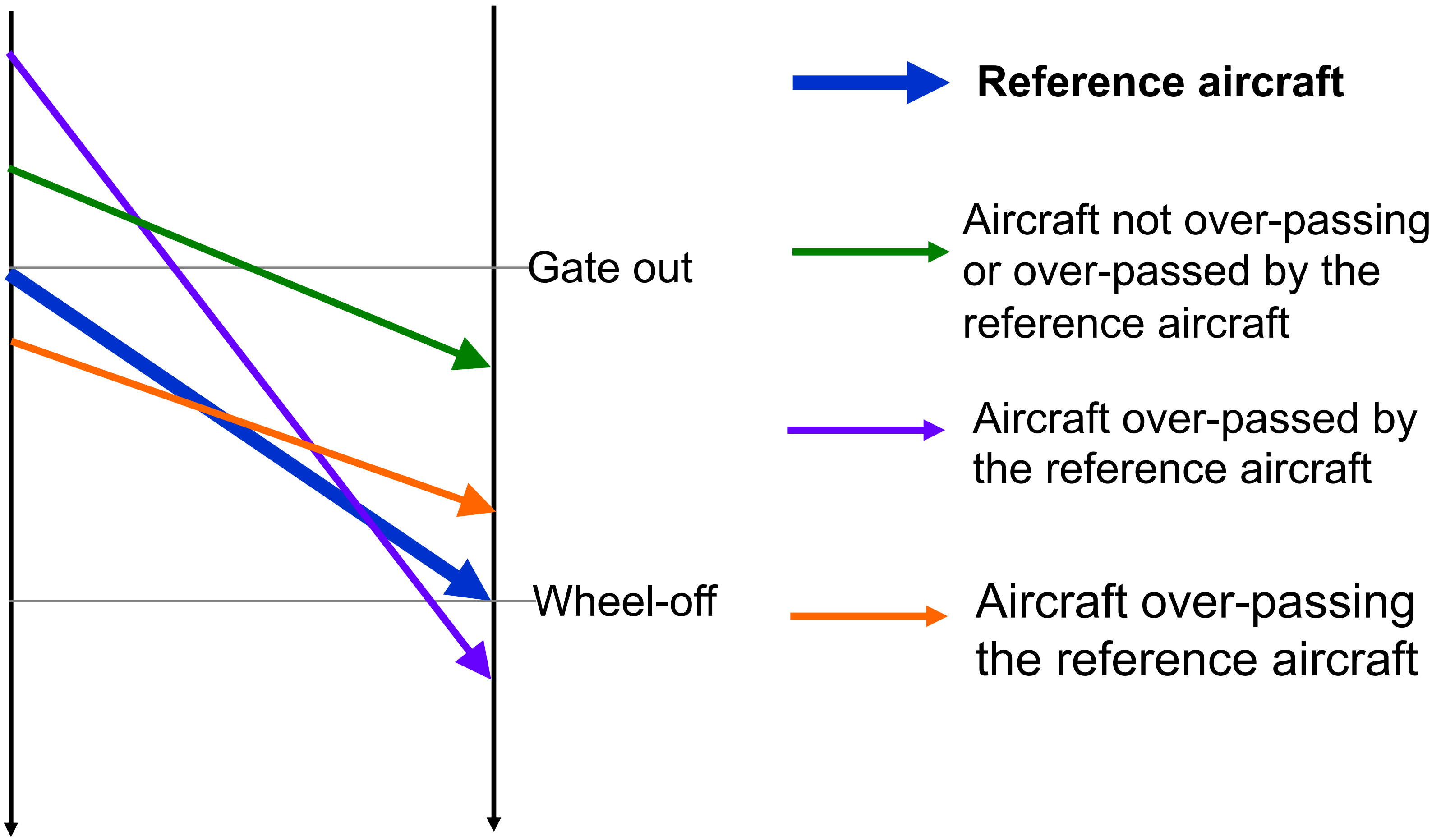
$$y_i = a' \cdot x_o + b' \cdot x_i + c'$$

Unimpeded taxi time:

$$y_o^* = a \cdot 1 + b \cdot 0 + c$$

$$y_i^* = a' \cdot 0 + b' \cdot 1 + c'$$

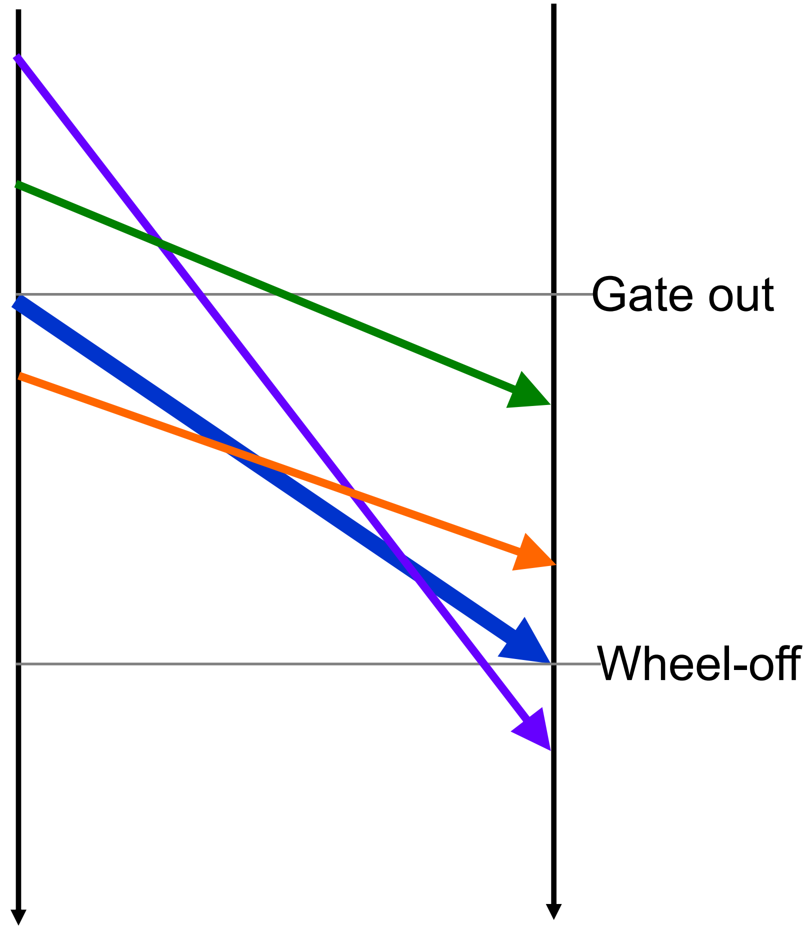
Aircraft Over Passing[1]



1. Idris et al, Queuing Model for Taxi-Out Time Estimation, 2002

Alternative Model

- Group: Origin-Destination, Carrier, Season
- Excluding the upper 25% taxiing time in estimation
- Departure queue length: the number of takeoffs that took place ahead of the reference aircraft during its taxi out.
- Arrival queue length: the number of aircraft that gated in ahead of the reference aircraft during its taxi in.



Alternative Model

- Group: Origin-Destination, Carrier, Season
- Excluding the upper 25% taxiing time in estimation
- Departure queue length: the number of takeoffs that took place ahead of the reference aircraft during its taxi out.
- Arrival queue length: the number of aircraft that gated in ahead of the reference aircraft during its taxi in.

Regression model:

$$T_o = \alpha \cdot q_o + \beta \cdot q_i + \gamma$$

$$T_i = \alpha' \cdot q_o + \beta' \cdot q_i + \gamma'$$

Unimpeded taxi time:

$$T_o^* = \alpha \cdot 1 + \beta \cdot 0 + \gamma$$

$$T_i^* = \alpha' \cdot 0 + \beta' \cdot 1 + \gamma'$$

Comparison of two Models

R-square Statistics	Existing Model	Alternative Model
Mean	**0.32**	**0.62**
Standard Error	0.01	0.01
Median	0.32	0.64
Mode	0.36	0.68
Standard Deviation	0.11	0.12
Sample Variance	0.01	0.02
Kurtosis	0.83	4.41
Skewness	0.33	-1.53
Range	0.79	0.87
Minimum	0.00	0.01
Maximum	0.79	0.88
Group	439	439

Decompose Taxi time

- Taxi time with scheduled departure and arrival demands assuming regular operational environment
- Taxi time affected by other factors

Iterative Algorithm for Decomposing Taxi Times

1. Initialization :

   $x_o^{(0)} \leftarrow 0$ and $x_i^{(0)} \leftarrow 0$

   iteration count n $\leftarrow 1$

   convergence parameter $\varepsilon = 0.005$

2. Given estimated coefficients from regression model, calculate

   $$t_o^{(n)} = a \cdot x_o^{(n-1)} + b \cdot x_i^{(n-1)} + c$$

   $$t_i^{(n)} = a' \cdot x_o^{(n-1)} + b' \cdot x_i^{(n-1)} + c'$$

3. Given scheduled departure time d and scheduled gate in time g_i

   calculate gate out time $g_o^{(n)} = d - t_o^{(n)}$

   and arrival time $a^{(n)} = g_i - t_i^{(n)}$

4. Calculate departure and arrival queue lengths $x_o^{(n)}$ and $x_i^{(n)}$, assuming no overpassing

5. Given estimated coefficients from regression model, calculate

   $$t_o^{(n+1)} = a \cdot x_o^{(n)} + b \cdot x_i^{(n)} + c$$

   $$t_i^{(n+1)} = a' \cdot x_o^{(n)} + b' \cdot x_i^{(n)} + c'$$

6. Convergence test :

   If $\sum_{f_a} \left(t_i^{(n+1)} - t_i^{(n)}\right) / F_a < \varepsilon$

   and $\sum_{f_d} \left(t_o^{(n+1)} - t_o^{(n)}\right) / F_d < \varepsilon$

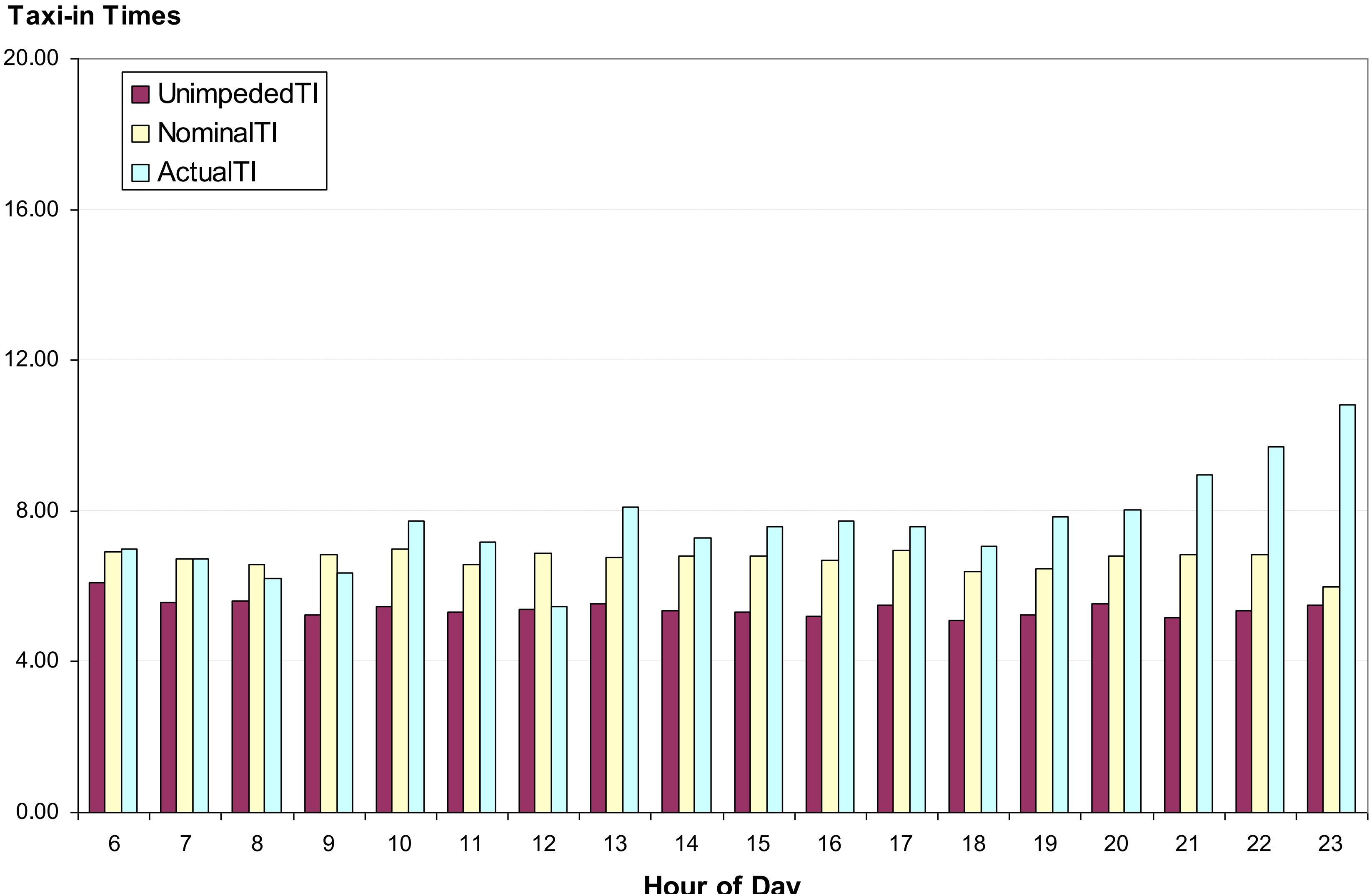
   stop

   else n $\leftarrow$ n + 1 and go to step 3

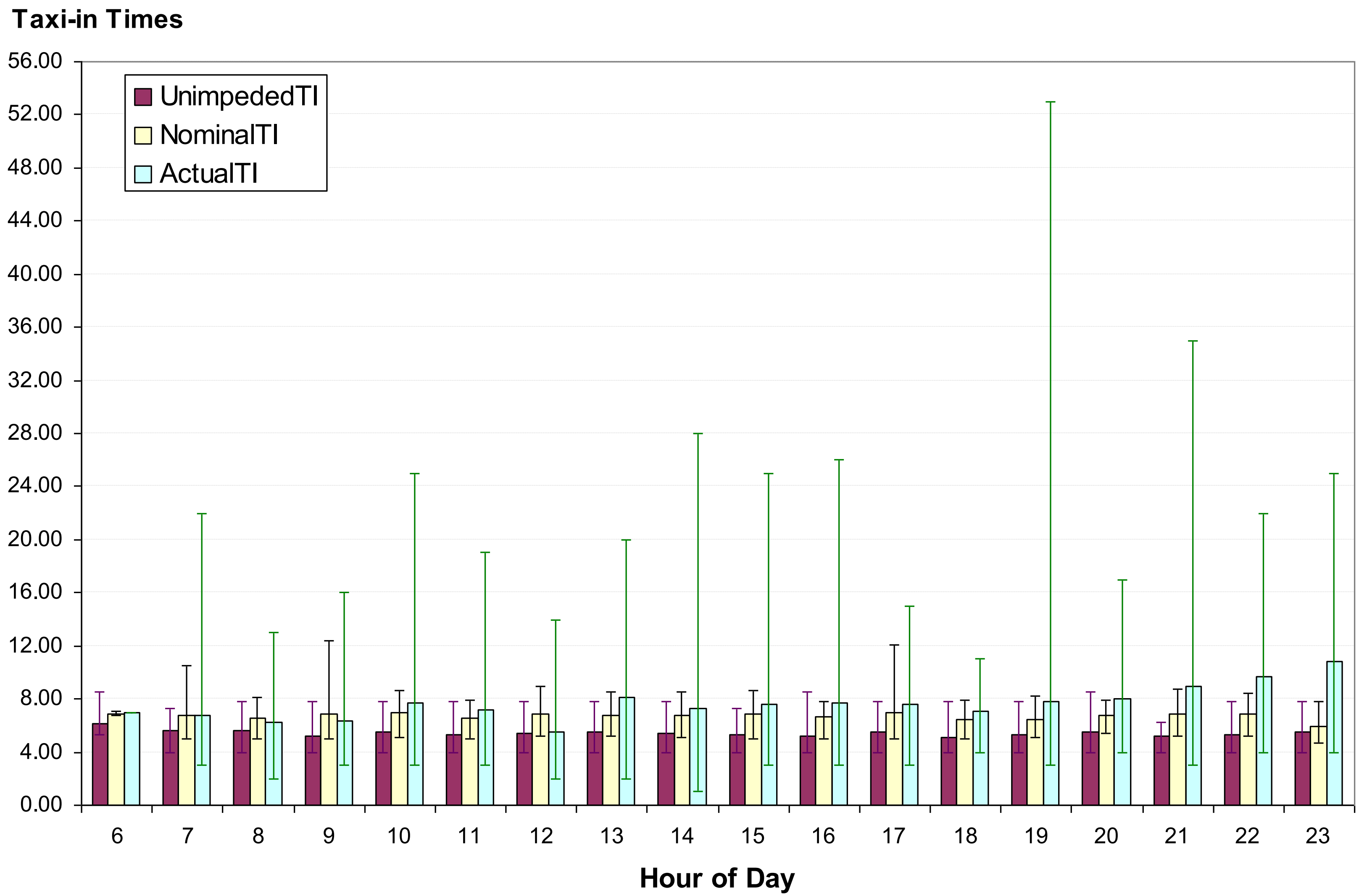
Numerical Example (Taxi-in)

	Unimpeded_TI	*Nominal_TI*	*Actual_TI*
Mean	5.39	6.74	7.50
Standard Error	0.04	0.05	0.21
Median	5.30	6.18	7.00
Mode	5.30	3.84	7.00
Standard Deviation	0.92	1.05	4.59
Sample Variance	0.84	1.10	21.08
Kurtosis	1.20	-0.87	25.82
Skewness	0.89	-0.13	3.84
Range	4.50	5.42	52.00
Minimum	4.00	3.84	1.00
Maximum	8.50	9.26	53.00
Sum	2467.00	2752.56	3433.00
Count	458	458	458

Taxi-in (Mean by Hour)



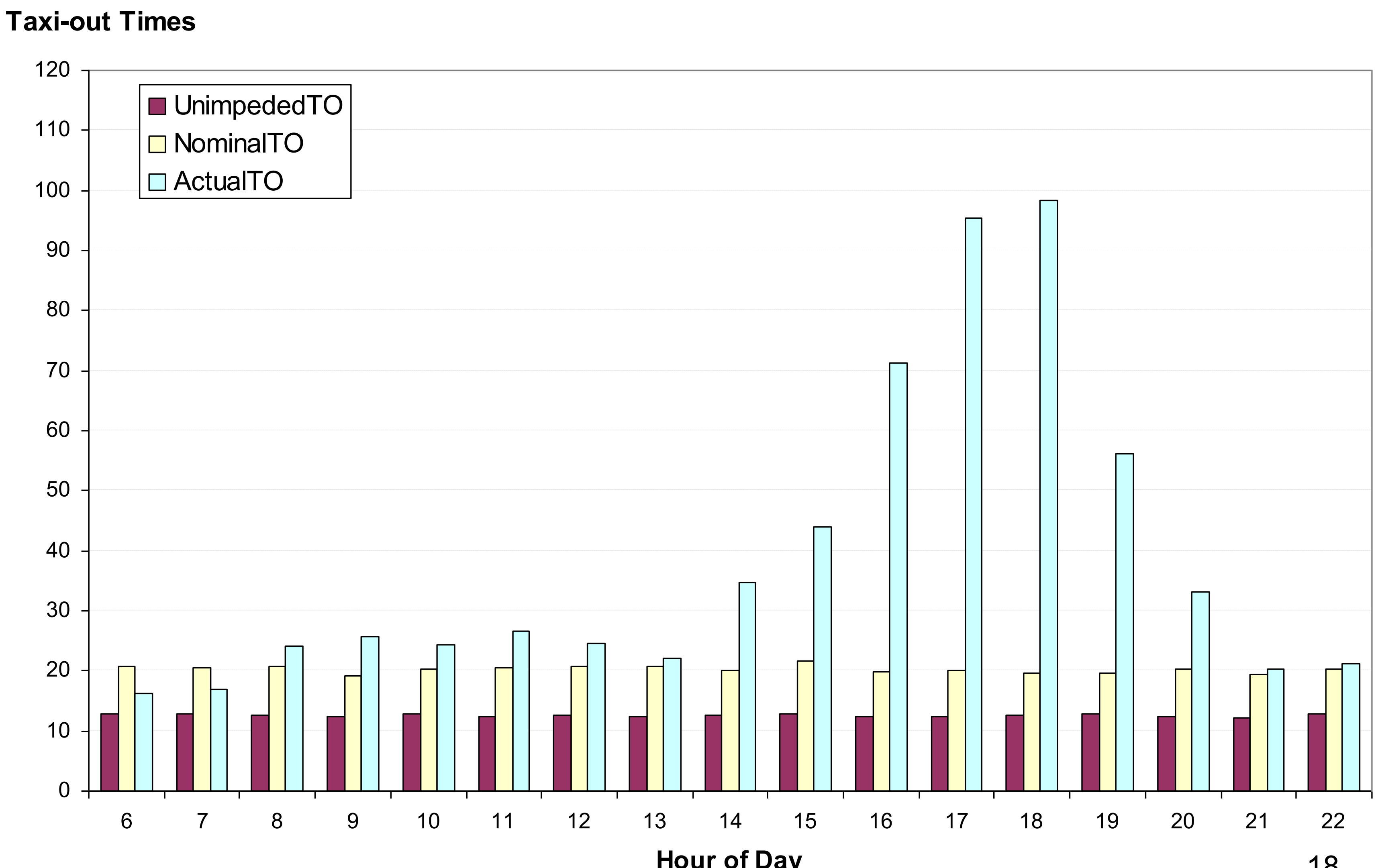
Taxi-in (Mean and Range by Hour)



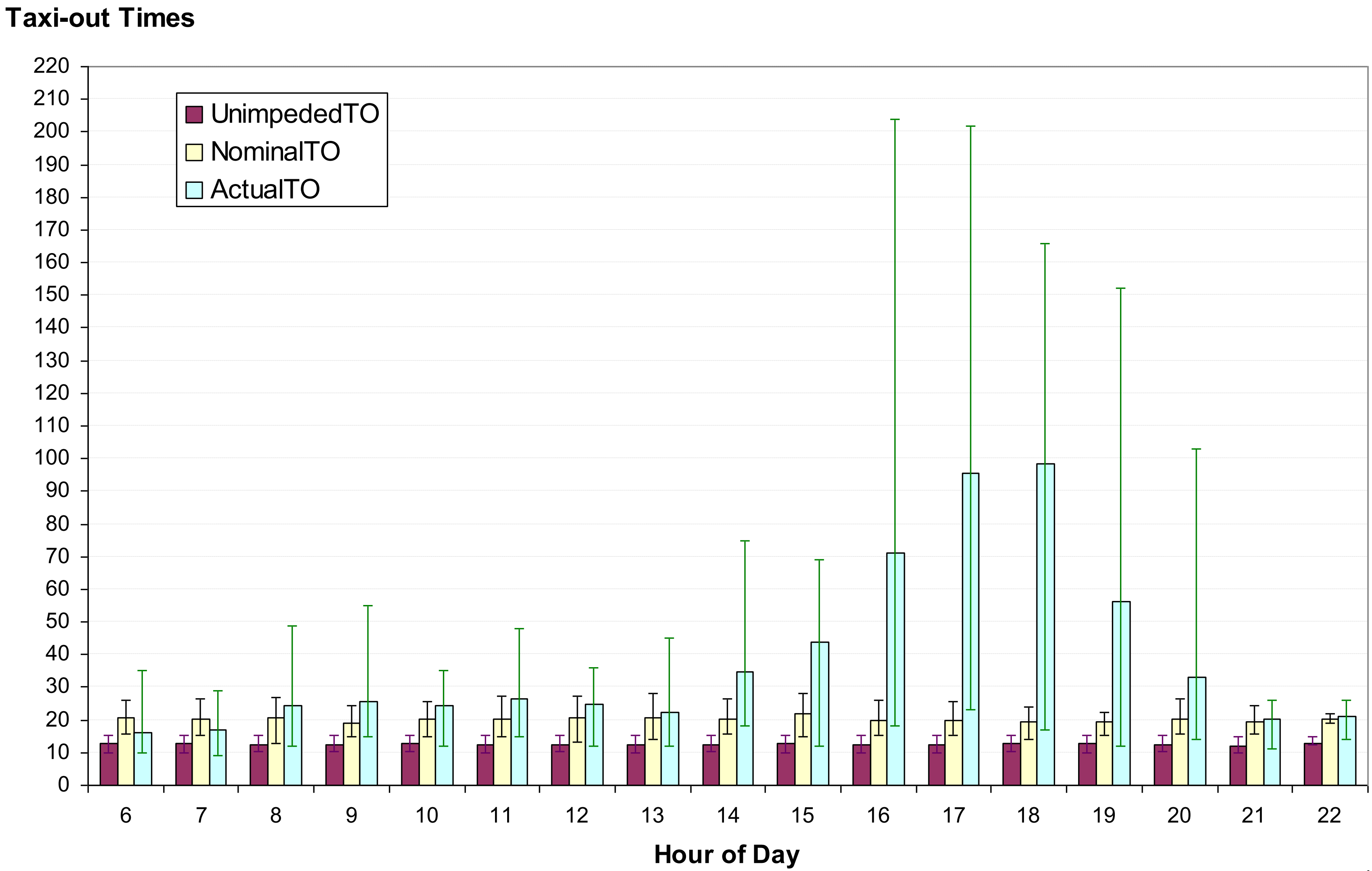
Numerical Example (Taxi-out)

	Unimpeded_TO	*Nominal_TO*	*Actual_TO*
Mean	12.60	20.29	37.56
Standard Error	0.07	0.12	1.56
Median	12.4	19.84	25
Mode	12.4	15.14	23
Standard Deviation	1.47	2.51	33.63
Sample Variance	2.16	6.29	1130.99
Kurtosis	-0.91	-0.13	7.52
Skewness	0.40	0.06	2.64
Range	5.1	13.55	195
Minimum	10.1	14.24	9
Maximum	15.2	27.79	204
Sum	5832.8	9333.19	17391
Count	463	463	463

Taxi-out (Mean by Hour)



Taxi-out (Mean and Range by Hour)



What is Next?

- Introducing quadratic components into the alternative models
- Analyze the effectiveness of taxi time models for a large set of airports
- Test the effect of different scheduling with the same daily total demand
- Investigate the effect of having more (double? Triple?) scheduled flights

Work in Progress (1)

- Integrated model for departure sequence and gate push-back time
  - Existing literature: Departure sequence with holding point constraint
  - Existing literature: Gate push-back time given departure sequence from SMS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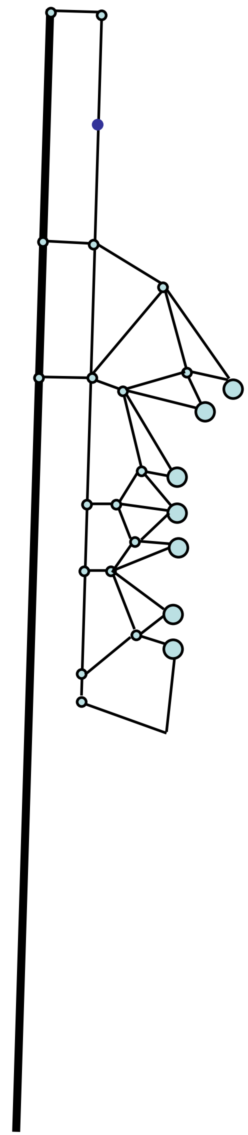
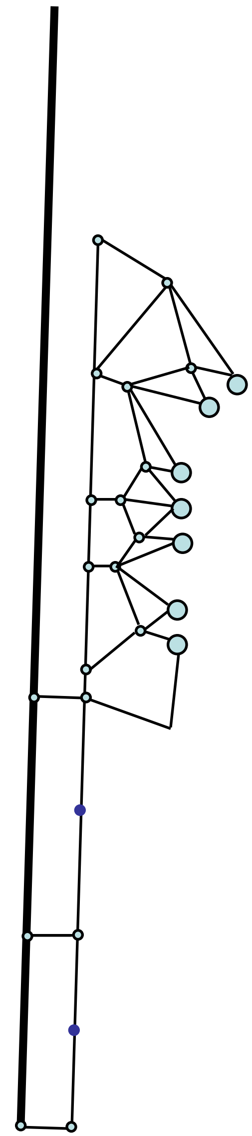
Google
Pointer 27°58'36.72" N 82°31'54.37" W elev 18 ft Streaming ||||||||| 100% Eye alt 14358 ft

18R





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Multiple Objective Optimization

- Maximizing operational throughput ↔ Minimizing late take-off penalty: pushing flight to take off in earlier time periods by penalizing takeoffs in later time periods heavier
- Minimizing taxiing time, including transverse time and taxiing delay
- Minimizing the penalty of deviating from scheduled departure time

Work in Progress (2)

- Impact of Airport Delay on National System
  - Analyze the delay trend at OEP airports
  - Investigate the change of delay concentration with topology tools
  - Quantify the impact of a single airport or regional airport system to NAS

Thank you !

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