Controlling Airport Runway Queues Under Variable Conditions

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Modeling and Simulation (DATA 604)

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Colab

Pushback control

- Planes burn fuel and generate emissions in the runway queue.
- A *pushback control scheme* controls when planes push back from the gate and enter the runway queue.
- A good pushback control scheme:
  - Ensures the runway is fully utilized;
  - Minimizes the length of the runway queue;
  - Thereby reduces fuel burn and emissions of planes waiting in runway queue.

Varieties of pushback control

- ***None***
  - All planes advance to runway queue as soon as they request pushback from the gate.
- ***Naïve***
  - For each time step, planes cleared to enter runway queue =
    total scheduled departures per day / time steps per day
- ***Smart***
  - Planes cleared to enter runway queue =
    runway capacity at $t + 2$ less planes already waiting on runway (Simaiakis et al.)

Pushback control depends on dubious schedules

- Naïve pushback control requires total expected departures for day.
- Smart pushback control requires runway capacity 2 timesteps ahead.
- ***What if actual events at the gate and runway deviate from schedules?***

Simulation question

Given that events at an airport can unexpectedly deviate from their schedules, what is the optimal pushback rate control scheme?

How can events deviate from schedules?

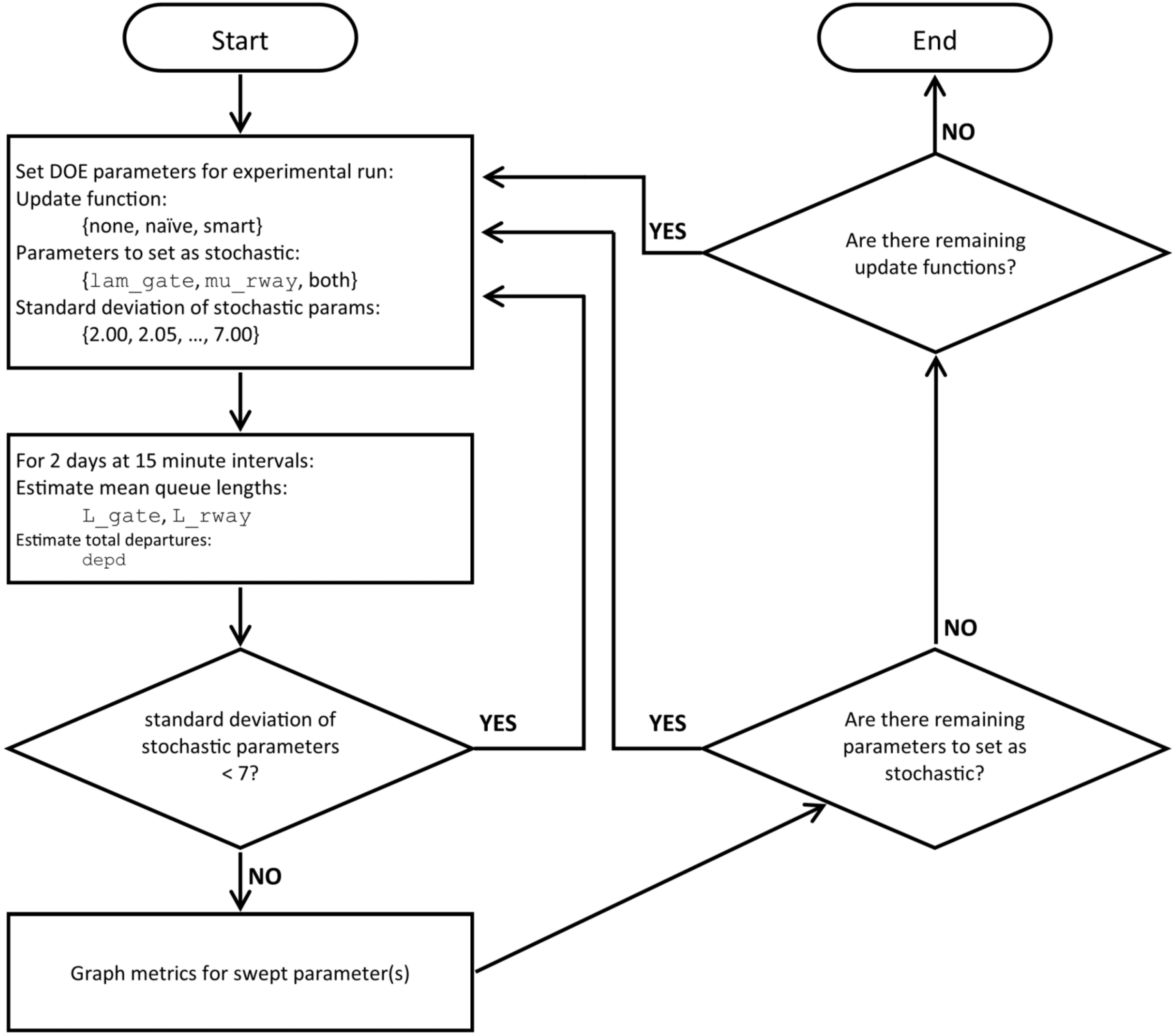
- The number of planes requesting pushback from the gate (== entry into the gate queue) can unexpectedly deviate from the schedule.
  - Denoted λ_g, `lam_gate`.

- The runway capacity can unexpectedly deviate from the schedule.
  - Denoted μ_r, `mu_rway`.

- Both λ_g and μ_r can unexpectedly deviate.

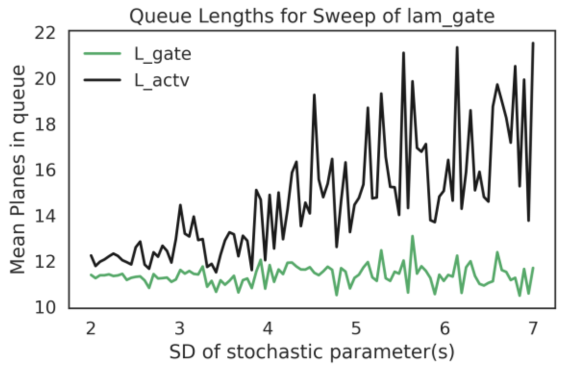
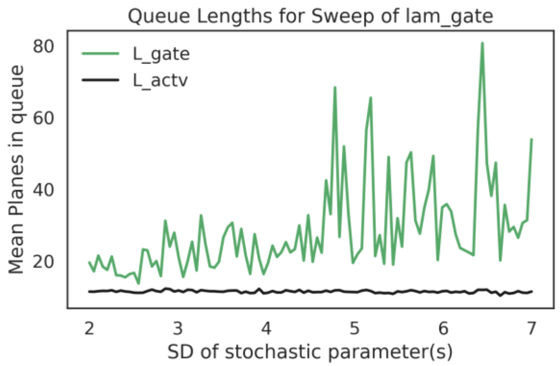
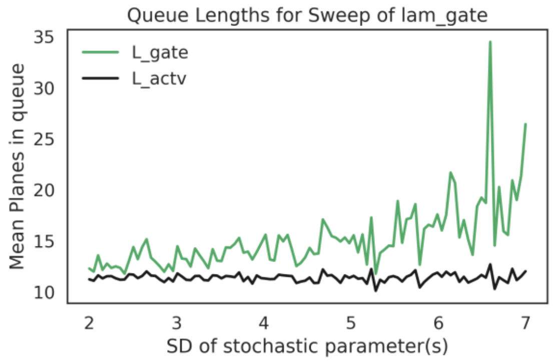
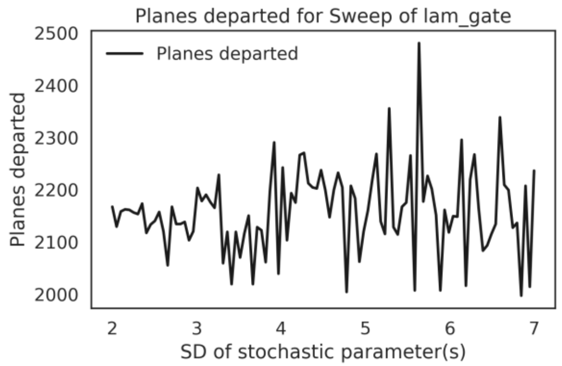
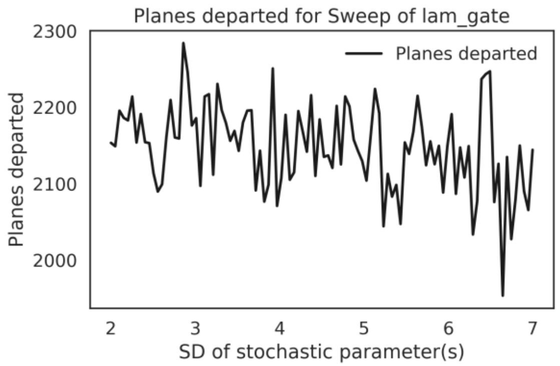
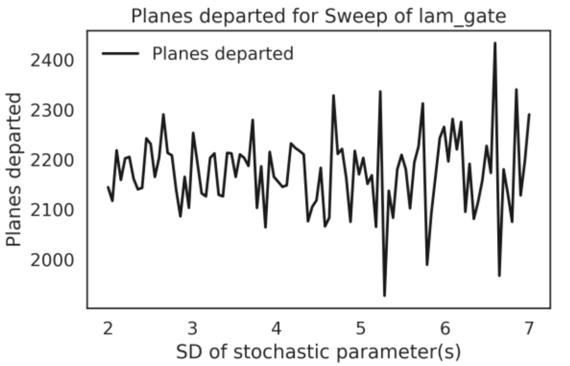
Modeling deviation from schedule

1. Choose a parameter allowed to deviate (λ_g or μ_r or both).
2. Choose a standard deviation in {2, 2.05, 2.10, …, 7}.
3. Look up scheduled parameter value for $t + 1$.
4. Build a normal distribution with:
   mean = scheduled parameter value for $t + 1$,
   sd = as chosen in step 2.
5. Sample 1 integer from this distribution.
6. Set the parameter at $t + 1$ equal to the value from 5.


Start
End
Set DOE parameters for experimental run:
Update function:
{none, naïve, smart}
Parameters to set as stochastic:
{lam_gate, mu_rway, both}
Standard deviation of stochastic params:
{2.00, 2.05, …, 7.00}
For 2 days at 15 minute intervals:
Estimate mean queue lengths:
L_gate, L_rway
Estimate total departures:
depd
standard deviation of stochastic parameters < 7?
YES
NO
Graph metrics for swept parameter(s)
Are there remaining parameters to set as stochastic?
YES
NO
Are there remaining update functions?
YES
NO

Results

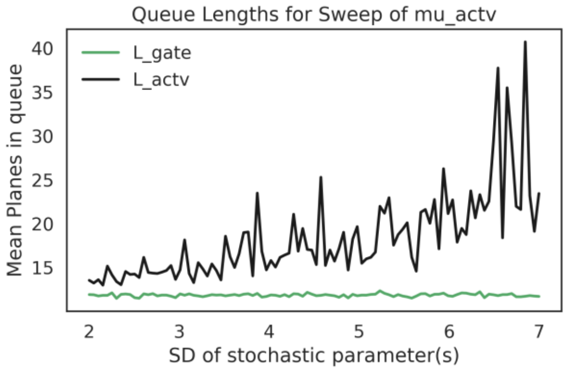
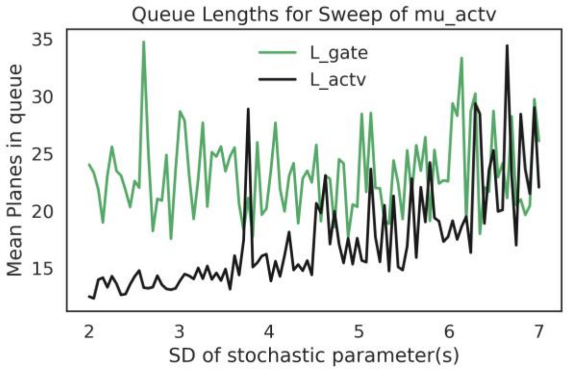
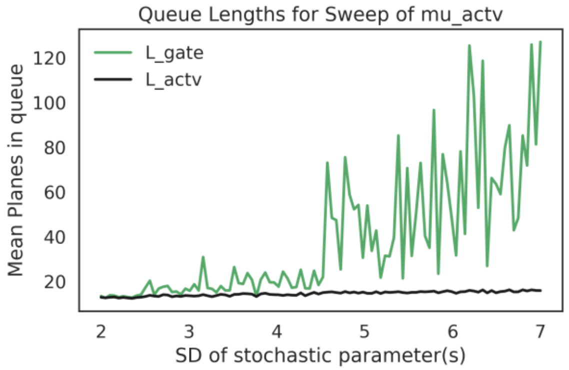
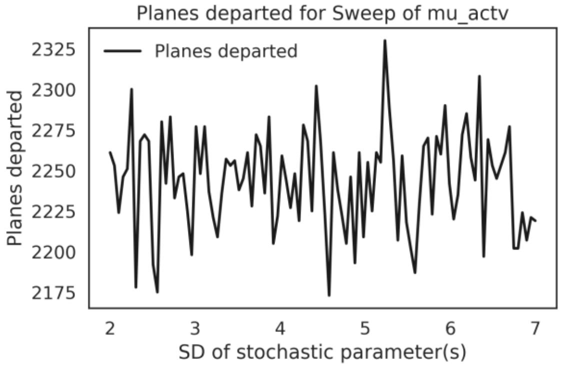
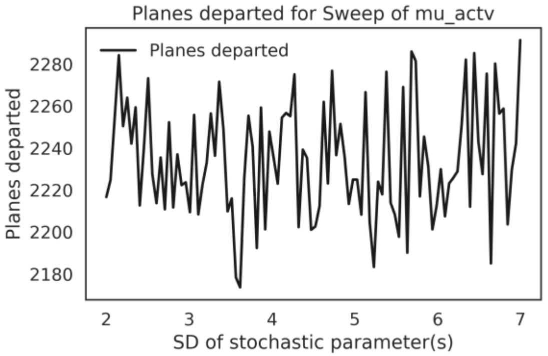
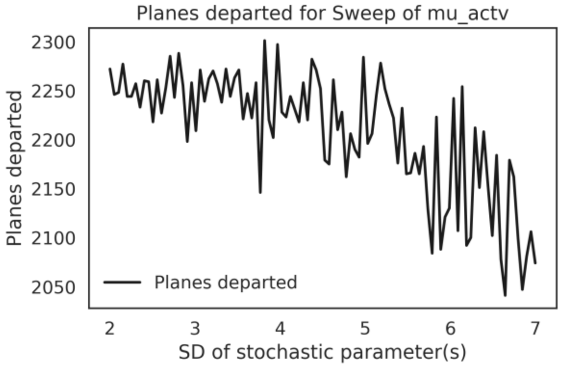
As deviation from pushback schedule increases, smart control performs best.

	No pushback control	***Naïve pushback control***	***Smart pushback control***
Queue lengths			
Total planes departed			

Typo: “mu_actv” should read “mu_rway.”

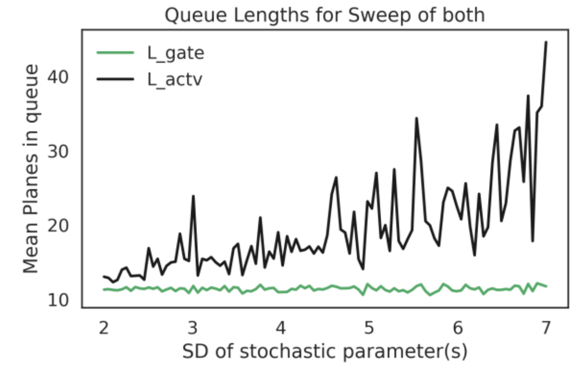
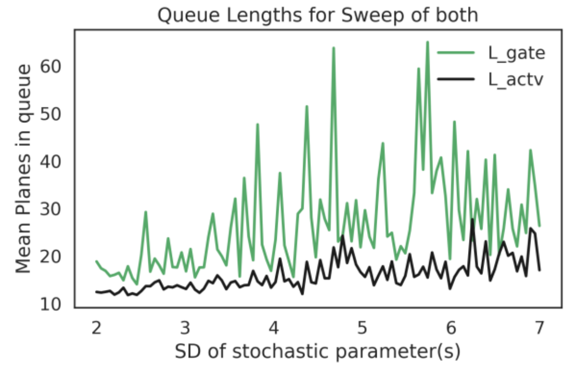
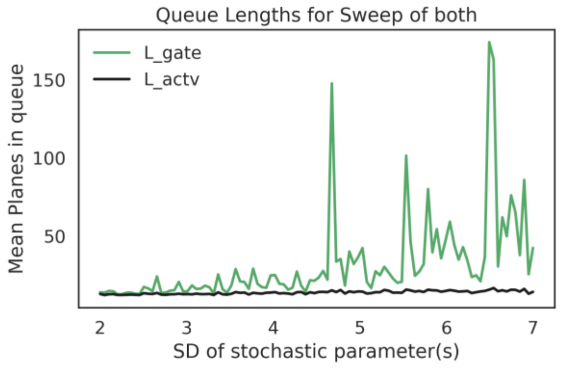
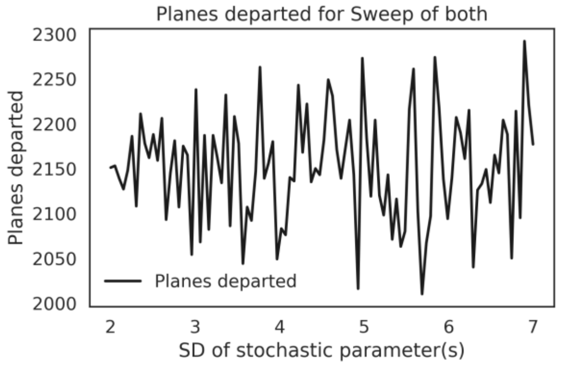
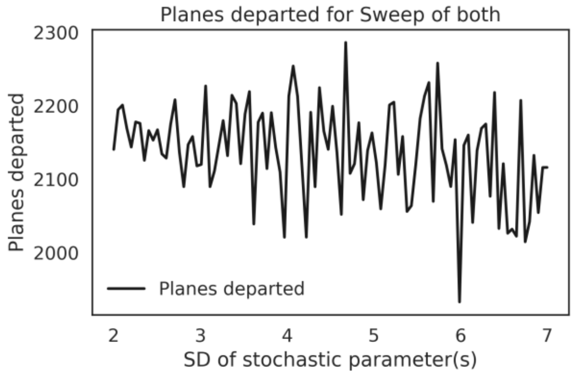
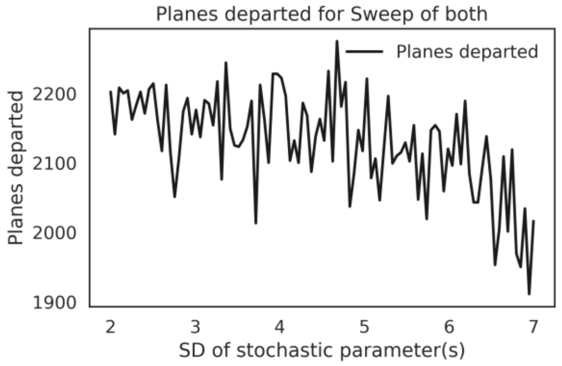
Results

When deviation from scheduled runway capacity is low, smart control performs best.
As deviation from scheduled runway capacity increases, naïve control performs best.

	No pushback control	***Naïve pushback control***	***Smart pushback control***
Queue lengths			
Total planes departed			

Results

With significant deviation from both schedules, naïve control performs best.

	No pushback control	***Naïve pushback control***	***Smart pushback control***
Queue lengths			
Total planes departed			

Discussion

- This simulation assumes that mean runway capacity slightly exceeds mean pushback rate from gate.
  - What if we varied mean runway capacity? Would this help accommodate greater deviations from schedules?
  - Would increased runway capacity (tighter schedules, greater reliance on technology) lead to greater deviations from schedules?

Works cited

- Badrinath, Sandeep, and Hamsa Balakrishnan. "Control of a non-stationary tandem queue model of the airport surface." 2017 American Control Conference (ACC). IEEE, 2017.

- Simaiakis, Ioannis, et al. "Demonstration of reduced airport congestion through pushback rate control." Transportation Research Part A: Policy and Practice 66 (2014): 251-267.