Minimizing congestion due to drivers searching for parking

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Curbside parking in Seattle

Image credit: Ana Arevalo, CBS, Washington DC

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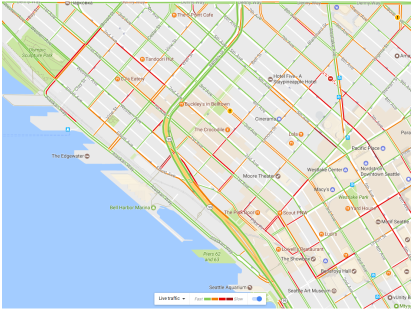
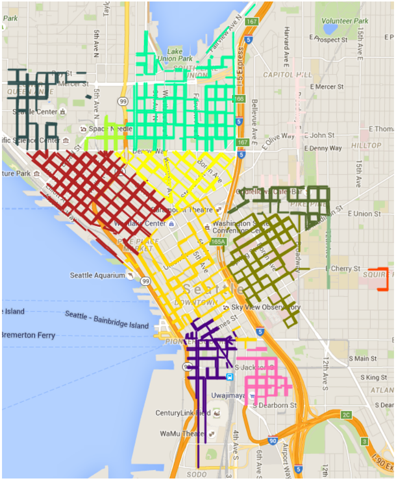


Estimated 30% of drivers on city streets searching for parking

Curbside parking in Seattle

30% is a big estimate

Is it correct? Can we minimize it?



Current Solutions

- Annual studies of parking resource performance

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- City: places like Oslo banning cars from city center (City) `http://www.popsci.com/oslo-decides-to-ban-cars-from-city-center`

Occupancy

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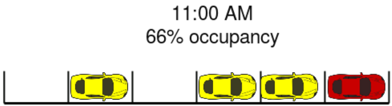
- Once required manual counting, can estimate with digital parking meters
- SDOT aims for an occupancy level in the range of 75%—85% on an hourly basis

Occupancy



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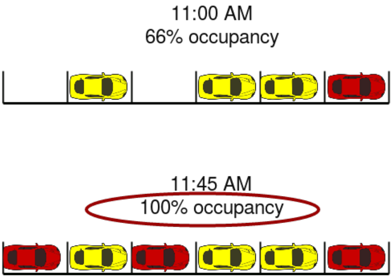

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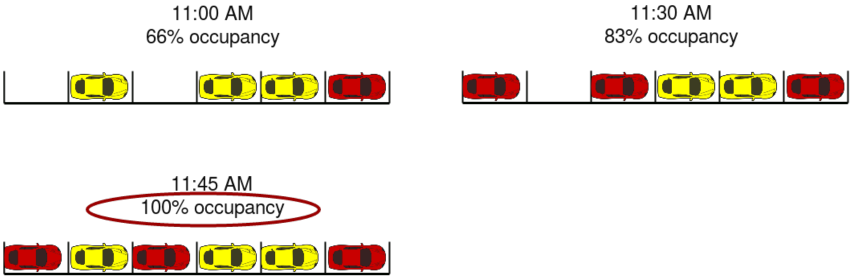
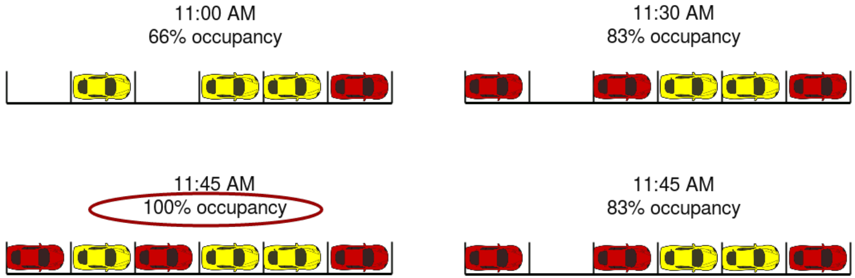

11:00 AM
66% occupancy
11:30 AM
83% occupancy
11:45 AM
100% occupancy

Occupancy



83% hourly occupancy

Research Questions

Can we determine the amount of congestion drivers searching for parking are responsible for?

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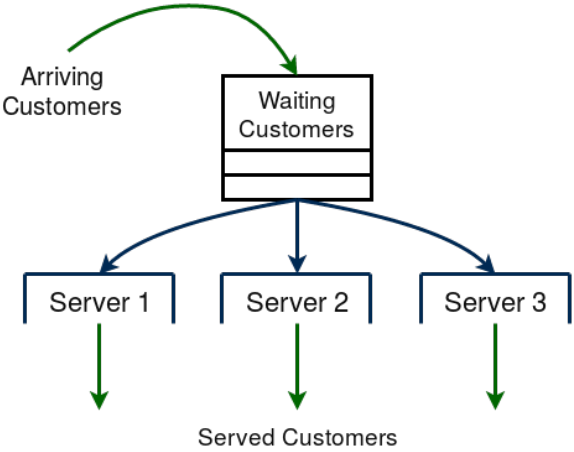
Let's model downtown curbside parking as a network of interdependent queues.

Contributions

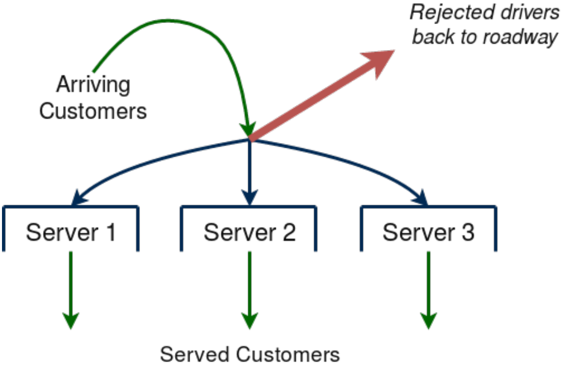
- Wrote a simulator for virtual drivers to search for parking in (`github.com/cpatdowling/net-queue`)
- We've shown that one can optimize parking availability subject to constraints on resulting congestion

Simulated occupancy levels in Belltown on a Monday morning

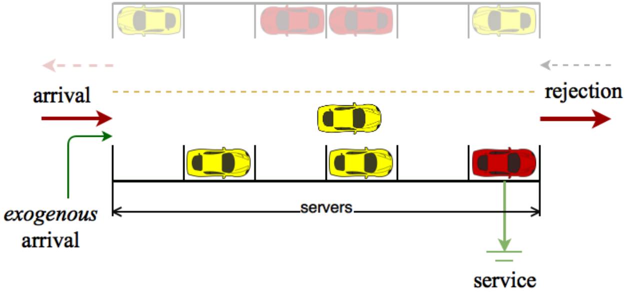
Multi-server Queue



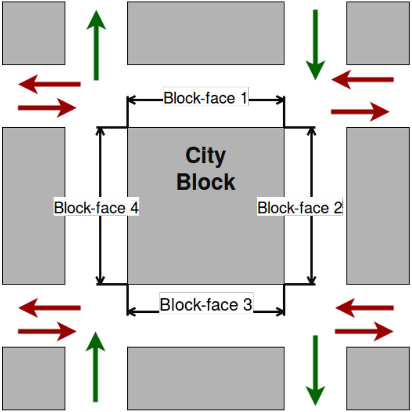
Bufferless Multi-server Queue

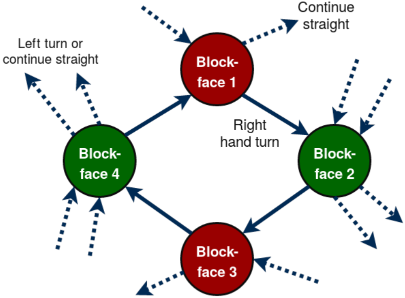


Block-face as a Queue



Block-face Queue Network





Data Sources

Data: IDAX, Seattle Dept of Transportation and `data.seattle.gov`

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- block-face latitude/longitudes
- spaces per block (number of servers)
- curbside parking transactions since 2012 at each block-face (service times)
- traffic volume by time of day on select arterials (superset of drivers parking)

SDOT Data

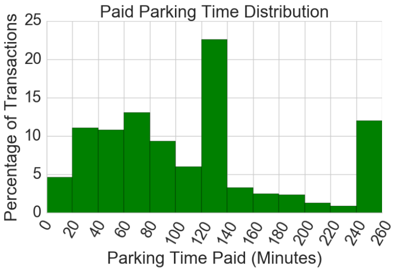

Figure 1: Distribution of transactions by paid parking time.

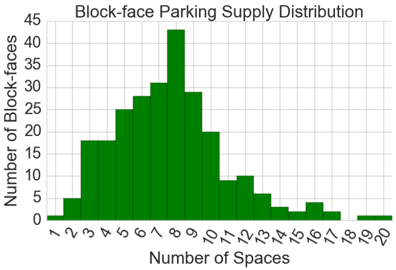

Figure 2: Distribution of parking spaces per block-face in Belltown.

Results

- First we'll gain some intuition in perfectly uniform networks

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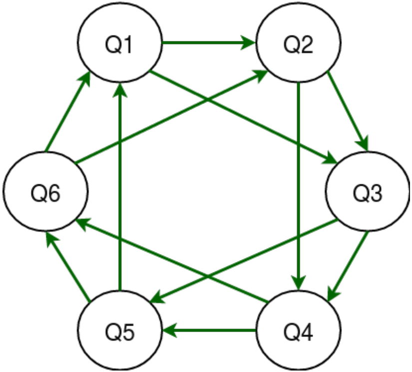
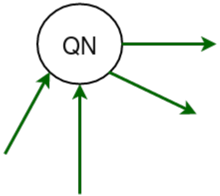
- We'll then analyze a real downtown network
- Then we'll clearly state the optimization problem to minimize congestion
- And we'll conclude with a hypothetical optimization result

Symmetric/Uniform Networks



- Uniform occupancy
- Equal in and out degree at each queue
- Equal service times
- Equal number of spaces
- Uniform search behavior

Symmetric/Uniform Networks



- Total arrival rate to each queue becomes solution to a polynomial
- Prove solution is unique, gives probability queue is full
- Can solve for rejection rate along each edge

Arrival Rates

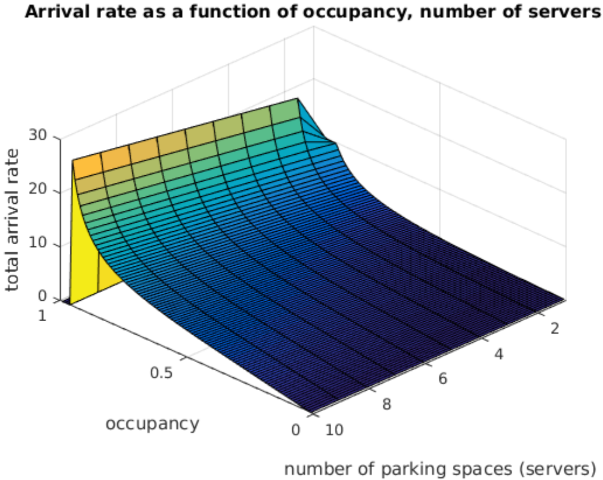
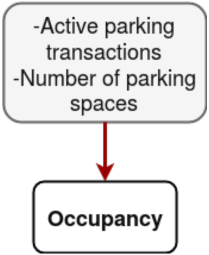


Figure 3: Arrival and rejection rate of vehicles is asymptotic in occupancy

Belltown Occupancy

Occupancy not uniform: `github.com/cpatdowling/demandviz`

Calculating Congestion from Data



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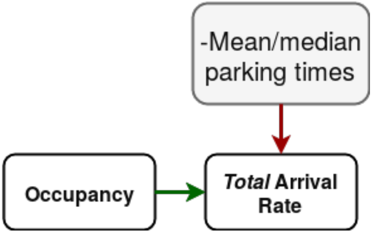

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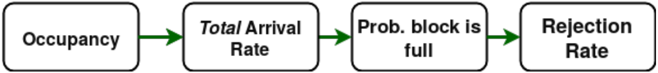

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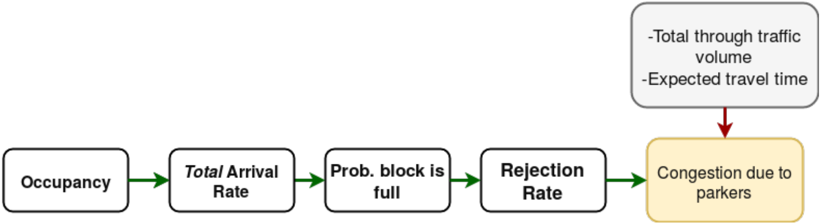


Congestion Caused by Parkers

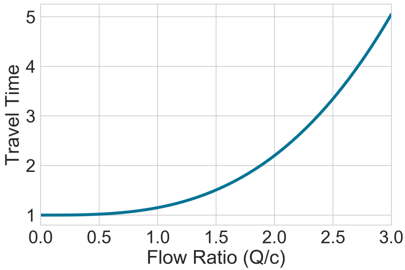


Figure 5: Approximation of travel time delay curve for signalized road

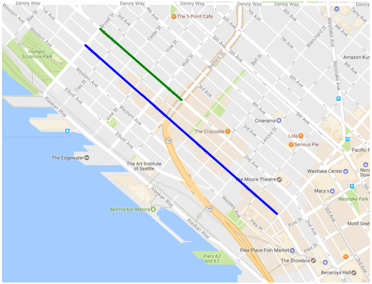


Figure 6: Belltown arterials with SDOT traffic volume data

Congestion Caused by Parkers

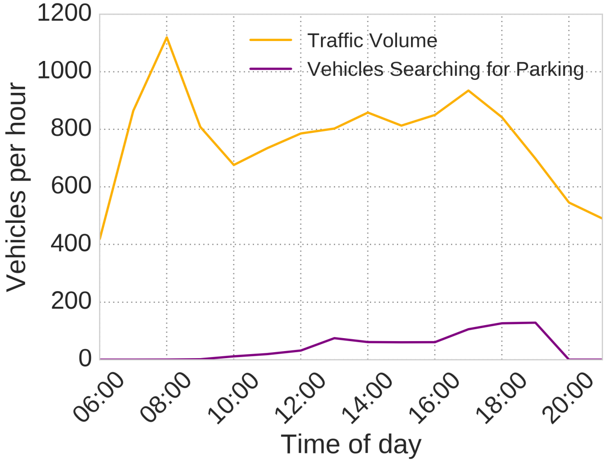
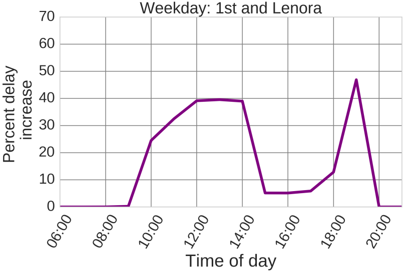
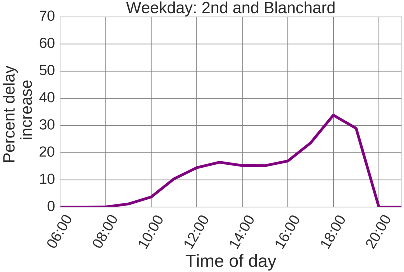


Figure 7: 2nd and Blanchard in Belltown

Congestion Caused by Parkers





Congestion Optimization

$$
\begin{aligned}
\underset{\mathbf{p}}{\text{maximize}} \quad & \text{Occupancy}(\mathbf{p}) \\
\text{subject to} \quad & \text{congestion along road } i;\, i = 1, \ldots, m.
\end{aligned}
\tag{P-1}
$$

Price Control Strategies

- **Seattle** Parking rates by morning/evening, weekday/weekend
- **San Francisco** Parking rates by *previous rate period's demand*, to time of day on a block by block basis

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price $\rightarrow$ desired demand level (occupancy) $\rightarrow$ queue probability of being full $\rightarrow$ rate of drivers unable to find parking (congestion)

Everything is convex!

Price Control in Mission District

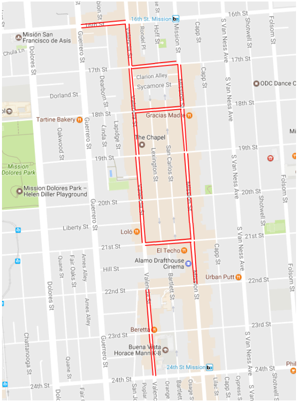


Figure 8: Curbside parking data in the Mission District of SF

- Price elasticity estimates from SFPark pilot study and companion 2013 study

Price Control in Mission District

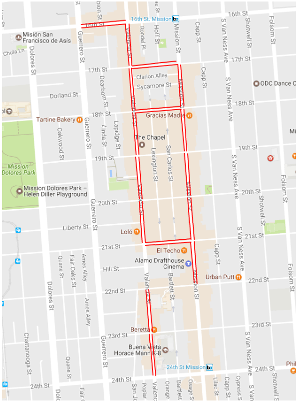


Figure 8: Curbside parking data in the Mission District of SF

- Price elasticity estimates from SFPark pilot study and companion 2013 study
- Gradient descent subject to an arbitrarily set maximum allowable rate of vehicles unable to find parking at each block-face.

Price Control in Mission District

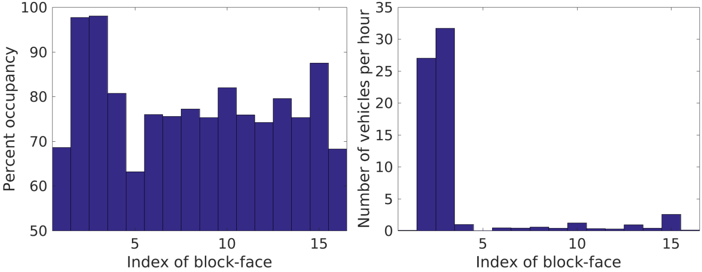
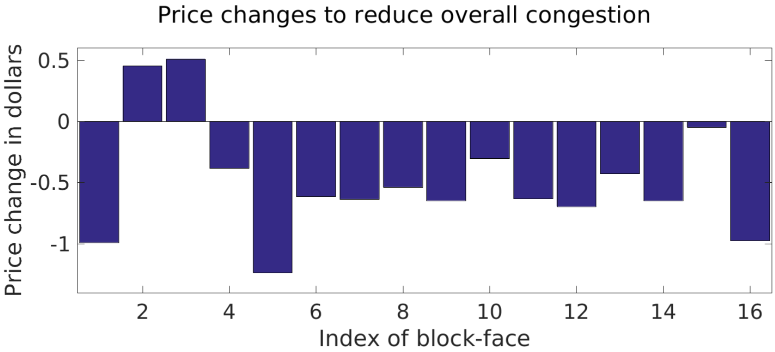


Figure 9: Noon weekday occupancy levels and resulting traffic estimates for Mission District, SF

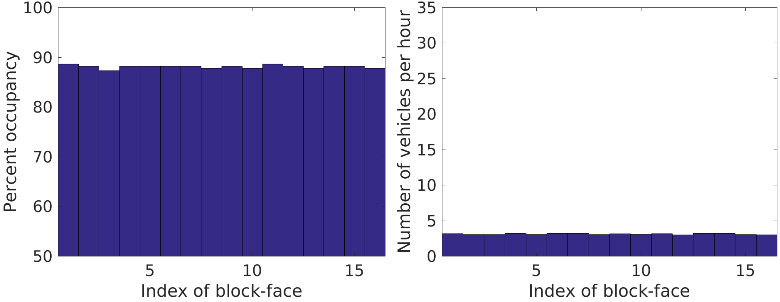
Price Control in Mission District

Noon weekday price changes to reduce rate of searching vehicles to no more than 1 per 12 minutes: Mission District, SF



Price Control in Mission District

Noon weekday controlled occupancy levels and resulting traffic estimates for Mission District, SF



Concluding Remarks

- Sharpen the "30% of traffic" estimate: depends on time of day *and* location

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- *Not* pricing against congestion due to individual drivers parking maneuvers

Future Work

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- Data-driven analysis of surface-street congestion: time delay due to volume

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- Data-driven analysis of surface-street congestion: time delay due to volume
- How does location factor into price elasticity?