designing the transit marketplace

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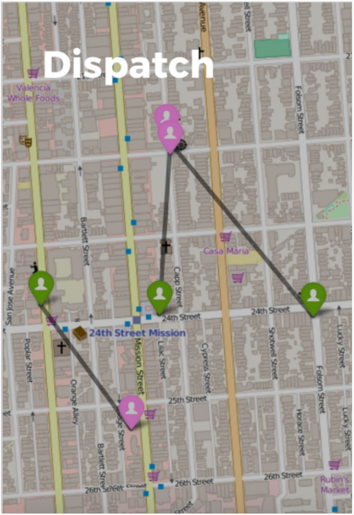
CNTS Workshop, July 2019

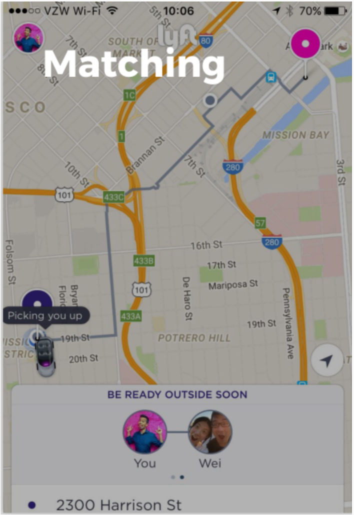
Operations Research, Cornell

ridesharing platforms

- critical components of modern urban transit
- crucible for real-time decision making/OR/EconCS

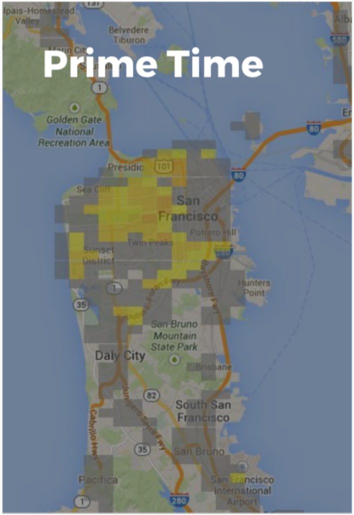
research in ridesharing: logistics

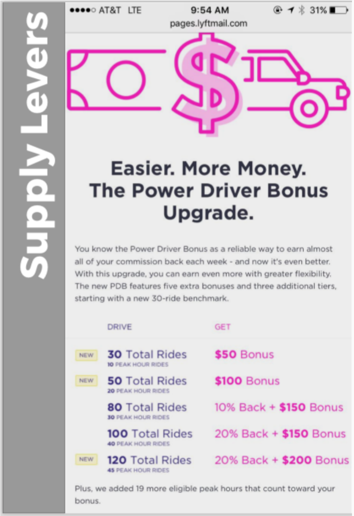




credit: lyft research science

research in ridesharing: market design





credit: lyft research science

shout-out to all my co-passengers

Daniel Freund

Raga G

Chamsi Hssaine

Ramesh Johari

Yash Kanoria

Thodoris Lykouris

Pengyu Qian

Carlos Riquelme

Samitha Samaranayake

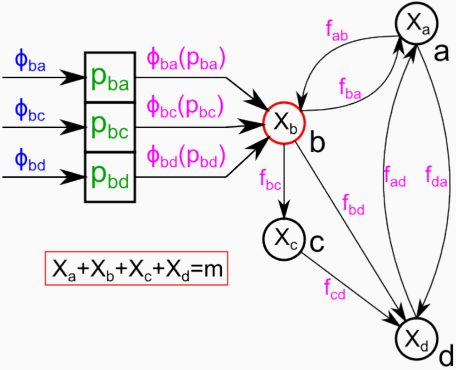
Thibault Séjourné

special shout out to

– the amazing folks in the lyft research science team

– ARO (W911NF-17-1-0094) & NSF (ECCS1847393, DMS1839346) support

what we have worked on



stochastic control models for ridesharing

Markov chain (queueing network) of cars in network

– available cats + occupied cars + empty-car rebalancing

– Poisson passenger arrivals, loss system

– state-dependent pricing/dispatch/rebalancing

what we can do

theorem [Banerjee, Freund & Lykouris 2017]

flow relaxation gives state-independent dispatch policy which is

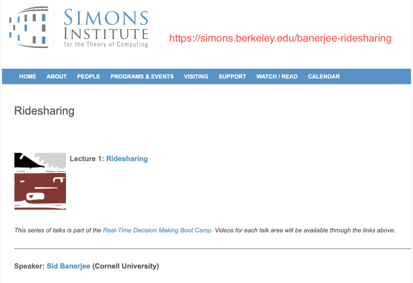
- $1 + \frac{n-1}{K}$ approximate (with instantaneous trips)
- $1 + O\left(\frac{1}{\sqrt{K}}\right)$ approximate (with travel-times, heavy-traffic)

theorem [Banerjee, Kanoria & Qian 2018]

family of state-dependent dispatch policies which are

- $1 + e^{-\Theta(K)}$ approximate (for large K, instantaneous trips)
- convex program gives optimal exponent

for more on this



survey chapter

Ride Sharing, Banerjee & Johari

in Sharing Economy, Springer Series in Supply Chain Management

so did ridesharing ‘solve’ transit?

(my view of) the next big challenge

two research vignettes

- impact of platform competition

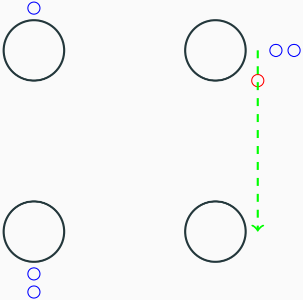
  ...and data vs. modeling

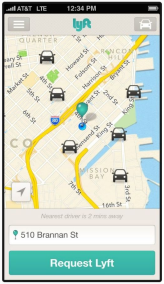
- designing transit marketplaces

  ...and the role of regulation

the price of demand fragmentation

price of fragmentation in ridesharing ecosystems



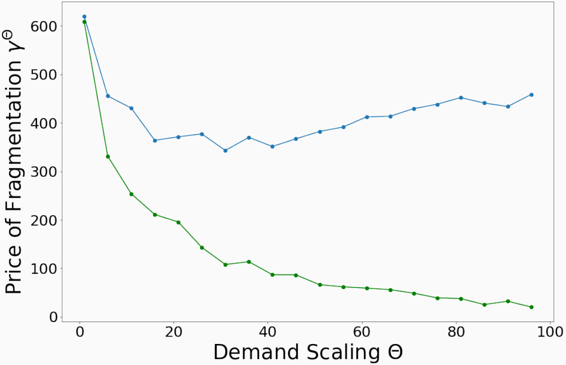


- ‘societal cost’ of decentralized optimization?
  - multiple platforms with exogenously partitioned demands
  - individual platforms do optimal rebalancing

price of fragmentation

under exogenous demand split, increase in rebalancing costs of multiple platforms vs. single platform (under large-market scaling)

counterfactual simulation: NYC taxi data



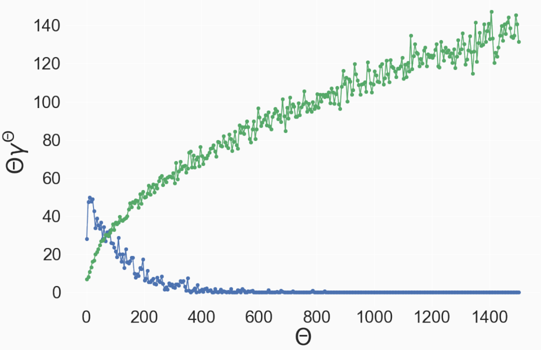
γ^θ vs. θ; NYC TLC data clustered into 40 stations

price of fragmentation in ridesharing markets

theorem [Séjourné, Samaranayake & Banerjee 2018]

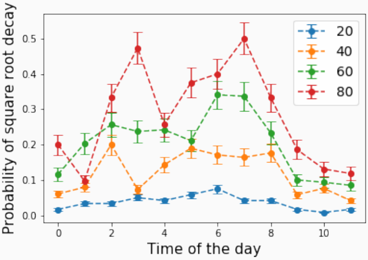
price of fragmentation undergoes a phase transition based on structure of underlying demand

– both regimes observed in NYC data ($\approx$ 10% fragmentation-affected)

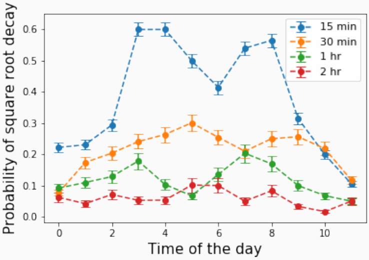


warning: affects numerical simulations in unpredictable ways

fraction of affected regimes depends on data-aggregation granularity (number of stations/time interval)



effect of spatial granularity



effect of temporal granularity

designing a transit marketplace

the transit marketplace

not yet, but...

FRIENDS
WITH TRANSIT

Exploring the intersection of Lyft and public transportation.

AARIAN MARSHALL TRANSPORTATION 10.24.17 07:00 AM

LA LOOKS TO RIDESHARE TO BUILD THE FUTURE OF PUBLIC TRANSIT

Coming soon to the Uber app: bikes, rental cars, and public transportation

Uber CEO Dara Khosrowshahi is in Washington, DC today to extend the hand of friendship to cities and make some product news

By Andrew J. Hawkins | @andyjayhawk | Apr 11, 2018, 10:30am EDT

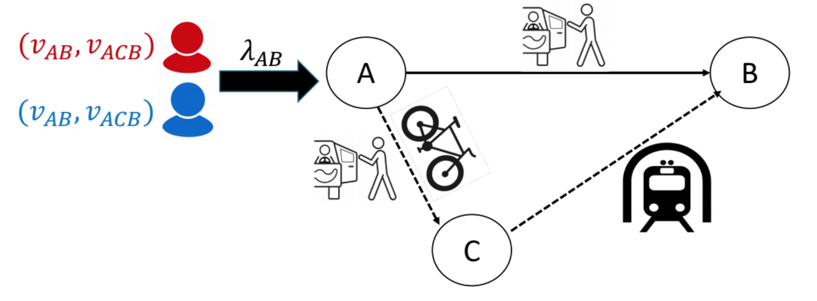
DART, Lyft creating new transit choices

A new collaboration between Dallas Area Rapid Transit (DART) and the ridesharing app Lyft means North Texas travelers have a great new way to begin, continue, or end their trip.

DART covers 700 square miles with a system of buses and trains connecting residents to major work, play, healthcare, and educational destinations. However, customers sometimes need a convenient way to start or end their trip. That's where ride sharing services like Lyft come in.

model

- each commuter has a public type
  - type = vector of valuations, one for each multi-modal option
  - we normalize transit value to 0
- market presents price-mode menu: price for each multi-modal option



transit marketplace: objectives

operational objective

reduce frictions, improve reliability for multi-modal trips

economic objective

set prices to maximize overall social welfare

is this all we care about?

pareto improvement as a desiderata for markets

Buy-in from *all* parties (providers and commuters) necessary for success

The Boston Globe

COMPUTERS CAN SOLVE YOUR PROBLEM. YOU MAY NOT LIKE THE ANSWER.

What happened when Boston Public Schools tried for equity with an algorithm

The New York Times

'Airbnb Tax' in N.J. Opens New Front in Battle Over Internet Economy

transit marketplace: objectives

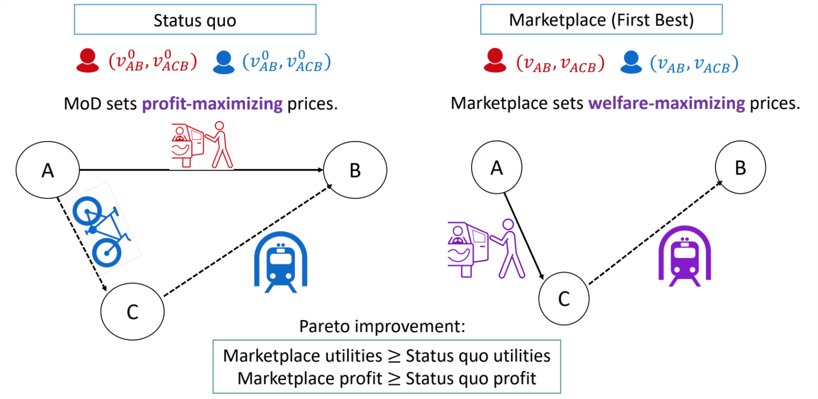
operational objective

reduce frictions, improve reliability for multi-modal trips

economic objective

set prices to maximize overall social welfare AND
ensure pareto improvement for all participants (commuters/firms)

transit marketplace: incorporating PI constraints



problem: these may be incompatible! (Myerson-Satterthwaite)

transit marketplace: preliminary results

1. Find welfare-maximizing prices (via LP).
2. Raises prices until one of three things happens:
   i. Efficient allocation is changed
   ii. Commuter-PI is violated
   iii. Enough money is raised

System of linear inequalities
Linear in size of input

3. Final prices:

$$p_m = p_m^* + \boxed{\Delta_{st}}$$

"Marketplace surcharge"

Informal Theorem. If there exist surcharges such that, for all commuters allocated a mode in the efficient allocation:

Worst-case welfare generated by commuter in marketplace

$$\max_m \left\{ \boxed{v_{\theta m}} - \boxed{\sum_{(i,j)\in E_m} (c_{ij} + c_{ji})} \right\} \geq \text{Status quo utility} + \text{Surcharge}$$

Valuation of commuter for mode m

Cost of m + local rebalancing

Welfare generated by commuter in status quo

and the surcharges make up the status quo profit, then First Best is Pareto-improving.

my view of the transportation landscape

where we stand

- transportation network control is real!
  - Lyft/Uber operate giant network control systems
- unified models for ridesharing
  - guide for designing good online controls (pricing/rebalancing)
  - sandbox for studying more complex problems

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the big challenge

- challenges of designing transit marketplaces
  - impact of competing network platforms
  - the role of regulation
  - re-optimizing the network: transit routes, number of cars, etc.

Thanks!