designing the transit marketplace

Sid Banerjee
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

Dispatch

Matching

credit: lyft research science
Prime Time


You know the Power Driver Bonus as a reliable way to earn almost all of your commission back each week - and now it's even better. With this upgrade, you can earn even more with greater flexibility. The new PDB features five extra bonuses and three additional tiers, starting with a new 30-ride benchmark.

<table>
<thead>
<tr>
<th>DRIVE</th>
<th>GET</th>
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<tbody>
<tr>
<td>NEW 30 Total Rides</td>
<td>$50 Bonus</td>
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<tr>
<td>NEW 50 Total Rides</td>
<td>$100 Bonus</td>
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<tr>
<td>80 Total Rides</td>
<td>10% Back + $150 Bonus</td>
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<tr>
<td>100 Total Rides</td>
<td>20% Back + $150 Bonus</td>
</tr>
<tr>
<td>NEW 120 Total Rides</td>
<td>20% Back + $200 Bonus</td>
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Plus, we added 19 more eligible peak hours that count toward your bonus.

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*
survey chapter

Ride Sharing, Banerjee & Johari
in Sharing Economy, Springer Series in Supply Chain Management
so did ridesharing ‘solve’ transit?

How Park-and-Ride Encourages Car Use
ERIC JAEFF MAR 20, 2013

A new study finds that people who used to make the whole trip by bike or transit now drive to the station.
(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

$\gamma^\theta$ vs. $\theta$; 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

Commuters | Price-setting platform | Providers

[Logos of Moov, Whim, and Ubigo]
FRIENDS WITH TRANSIT

Exploring the intersection of Lyft and public transportation.

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 | @andyjshawk | Apr 11, 2016, 10:30am EDT

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.
transit marketplace

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

\[(v_{AB}, v_{ACB})\]

\[\lambda_{AB}\]

\[(v_{AB}, v_{ACB})\]
### 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

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<td>set prices to maximize overall social welfare AND ensure pareto improvement for all participants (commuters/firms)</td>
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transit marketplace: incorporating PI constraints

Status quo

MoD sets \textit{profit-maximizing} prices.

Marketplace (First Best)

Marketplace sets \textit{welfare-maximizing} prices.

Pareto improvement:

Marketplace utilities $\geq$ Status quo utilities
Marketplace profit $\geq$ Status quo profit

\textbf{problem:} these may be incompatible! \textit{(Myerson-Satterthwaite)}
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
3. Final prices:
   \[ p_m = p_m^* + \Delta_{st} \]

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

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

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
### 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)
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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!