Uber Load-Rebalancing for Predictable Demand Spikes

April 30, 2018

Concept

Problem

Handling demand spikes is a difficult problem, currently being resolved using surge pricing.

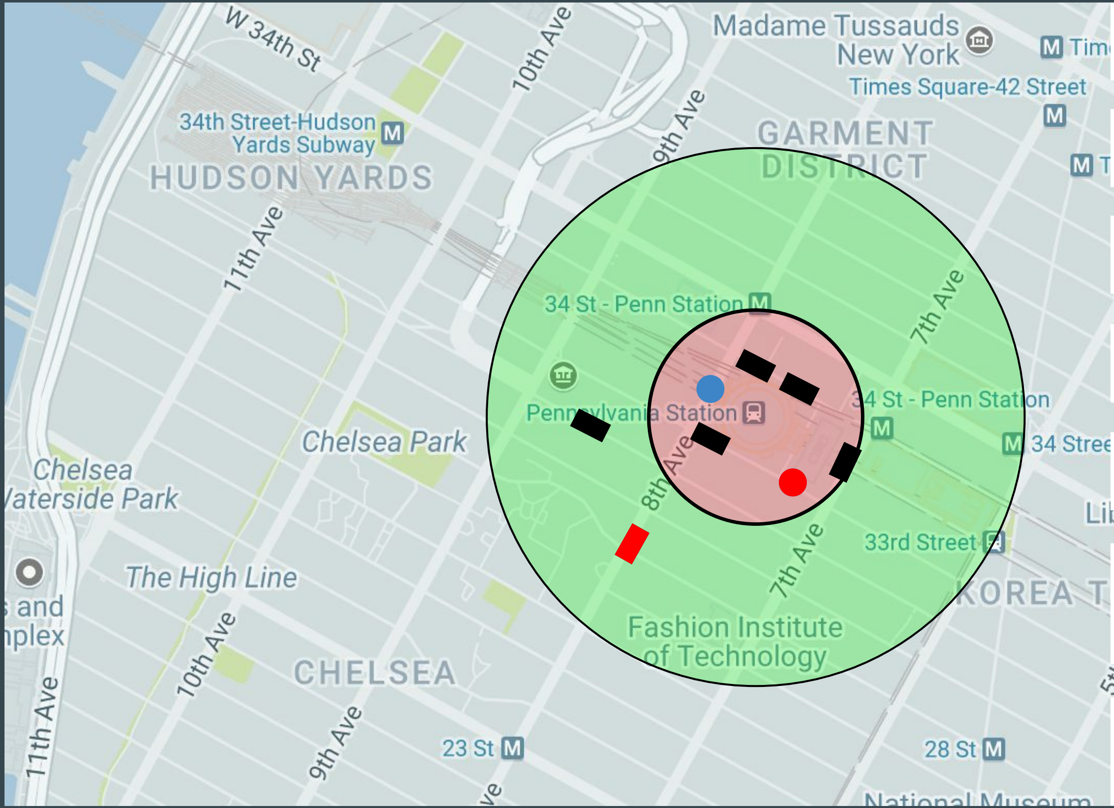
Observation

Not all demand spikes are unpredictable

Goal

Create a proactive policy in place of a reactive policy to maximize revenues during predictable demand spikes

Model Details



Location 1

Location 2

Drivers are distributed in each location

Customer arrivals ~ Pois(D_i)

Customers match with drivers

Customers accept match according to choice model given distance and price

Ubers can relocate prior to demand spike at some cost

Model Overview

- Model 1 - Relocation with Perfect Prediction
- Model 2 - Sensitivity of Relocation Cost and Incremental Revenue
- Model 3 - Simulation with Perfect Prediction
- Model 4 - Simulation with Imperfect Prediction

Model Parameters

Parameter	Description	Parameter Type
x_{ij}	P(customer in location i selects Uber in location j)	Estimated
c_{ij}	Cost(relocating Uber from location i to location j)	Estimated
N_{0j}	# of Ubers in location j **BEFORE** relocation	Estimated
N_{1j}	# of Ubers in location j **ATER** relocation	Model Output
D_j	True Demand in location j	Estimated / Model Parameter
r	Revenue from pickup up a customer	Estimated
m_{ij}	# of Ubers relocated from location i to location j	Model Output / Decision Variable
y_{ij}	# of people who open app in location i matched with car from location j	Model Output / Decision Variable

Model 1 - Relocation with Perfect Prediction

$$\max \sum_i \sum_j y_{ij} x_{ij} r - m_{ij} c_{ij}$$

$$\text{such that } N_{1j} = N_{0j} + \sum_i m_{ij} - \sum_i m_{ji} \quad \forall j$$

$$N_{0j} \geq \sum_i m_{ji} \quad \forall j$$

$$y_{ij} \geq 0 \quad \forall i, j$$

$$\sum_j y_{ij} \leq D_j \quad \forall i$$

$$\sum_i y_{ij} x_{ij} \leq N_{1j} \quad \forall j$$

13.7%

Increase of Total **Profit**

Model 2 - Sensitivity of Relocation Cost and Revenue

$$\max \sum_i \sum_j \alpha \cdot y_{ij} x_{ij} r - (1-\alpha) \cdot m_{ij} c_{ij}$$

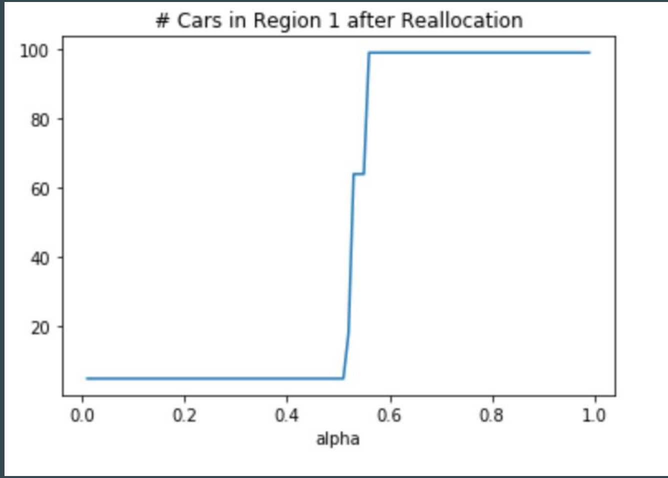
$$\text{such that } N_{1j} = N_{0j} + \sum_i m_{ij} - \sum_i m_{ji} \quad \forall j$$

$$N_{0j} \geq \sum_i m_{ji} \quad \forall j$$

$$y_{ij} \geq 0 \quad \forall i, j$$

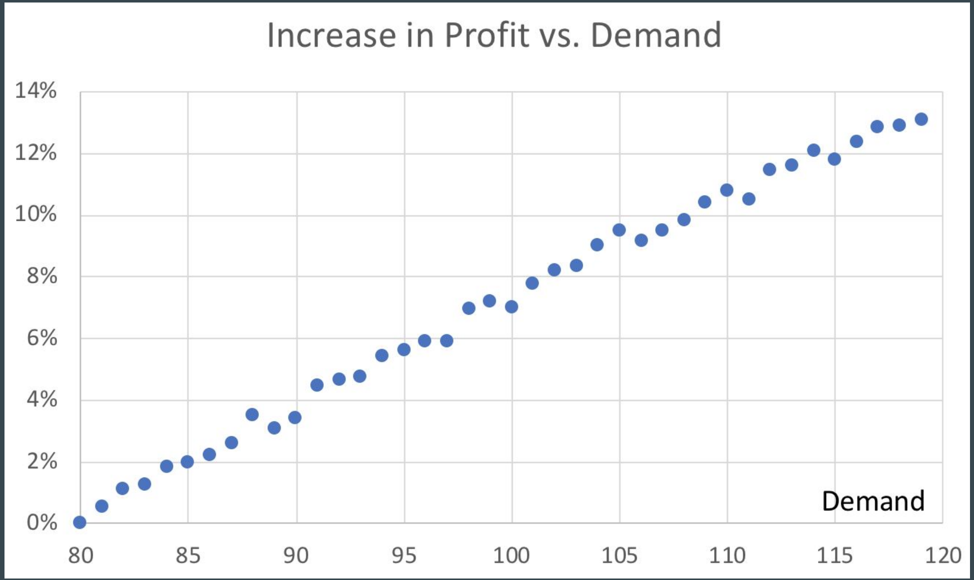
$$\sum_j y_{ij} \leq D_j \quad \forall i$$

$$\sum_i y_{ij} x_{ij} \leq N_{1j} \quad \forall j$$



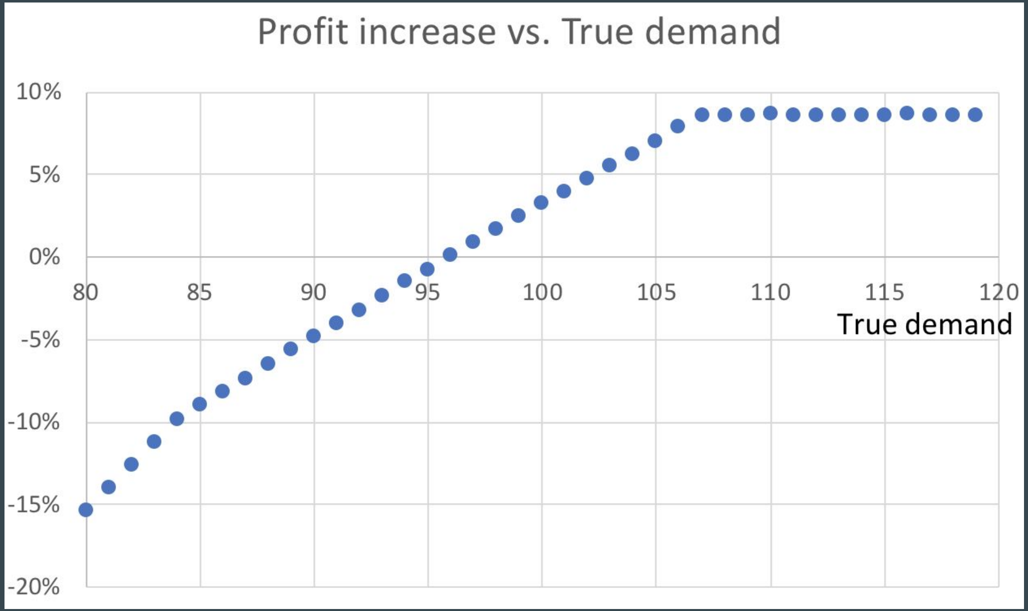
Model 3 - Simulation with Perfect Prediction

After moving cars inwards based on optimization predictions, we can expand profits *given* that there is indeed a demand spike big enough.



Model 4 - Simulation with Imperfect Prediction

As long as we don’t overestimate demand by more than 4%, our model is robust.



Conclusion

Additional Analyses

- Finding the optimal surge price
- Identifying the demand spike threshold
- Developing incentives program to not undersupply or oversupply

Additional Economic Benefits

- Drivers have reliable places to go
- Less frequent surge pricing
- More customer loyalty