From Data to Models and Proposed Solutions

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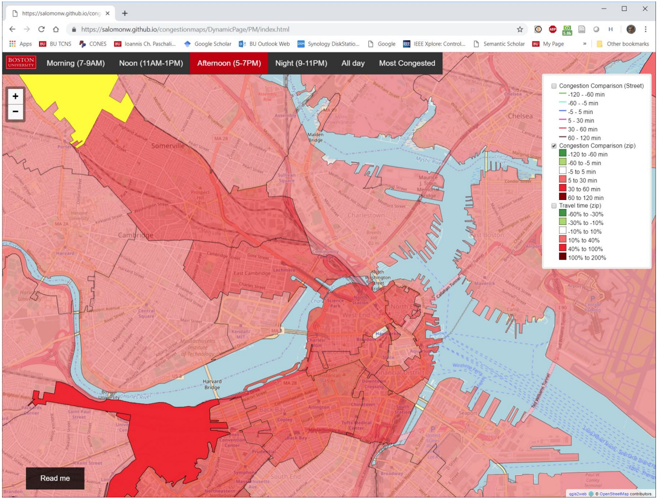
The problem


- Traffic congestion responsible for 20% of fuel consumption and 90% of CO in large urban areas.
- Cost of traffic congestion will reach \$2.8T in the US by 2030 ($\approx$ annual tax revenue).
- On a per-driver basis, cost of traffic congestion is \$1740 annually in US/Europe.
- Boston recently made news being declared #1 in hours lost in rush-hour traffic per driver in 2018.

Congestion Maps for the Boston Area: 2012→2015

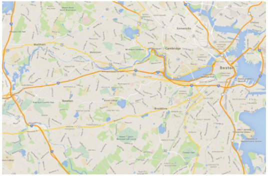


https://salomonw.github.io/congestionmaps/DynamicPage/PM/index.html

(Salo Wollenstein)

Transportation Network Models

- Transportation network modeled as a graph.



- Dynamics: Drivers have a congestion function function of flow for each arc and pick the cheapest arcs to traverse. Collective decisions lead to a Nash (Wardrop) equilibrium.
- To control/design we need to build accurate predictive models.
- Data: Traffic flows.
- Can we learn (the congestion function) from data?

Price of Anarchy[1]

- Having the congestion function allows us to answer many "what-if-questions".
- We can also formulate a problem to obtain a socially optimal equilibrium.
- Price-of-Anarchy:

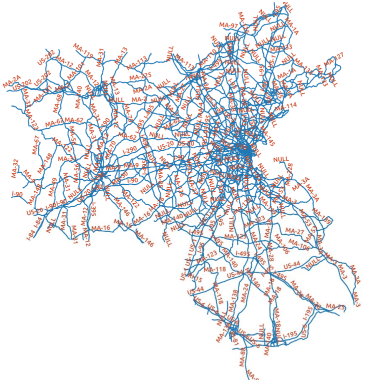
$$\text{PoA} = \frac{\text{Congestion under Selfish Behavior}}{\text{Congestion under Socially Optimal Behavior}}$$

- Useful to assess how good/bad things are, but also to design interventions.

[1] Zhang, Pourazarm, Cassandras, Paschalidis, CDC 2016, IFAC 2017, Proceedings IEEE 2018.

Boston Area Data[2]

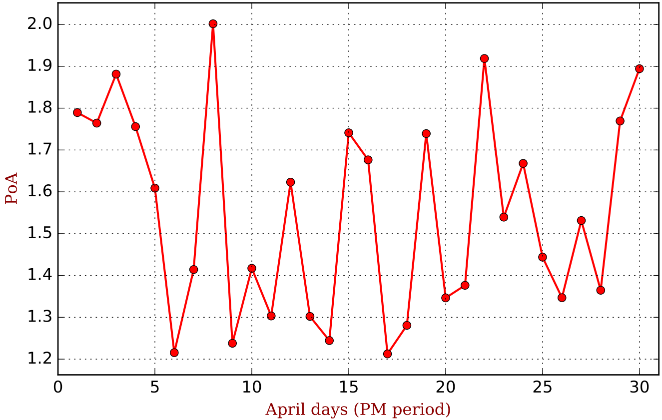
Eastern Massachusetts (EMA) Network



- Spatial average speeds for 13,000 road segments for each minute of 2012 (50 GB) and 2015 (130 GB).
- Capacity data in different times-of-day: lanes, peak vehicles counts, etc.

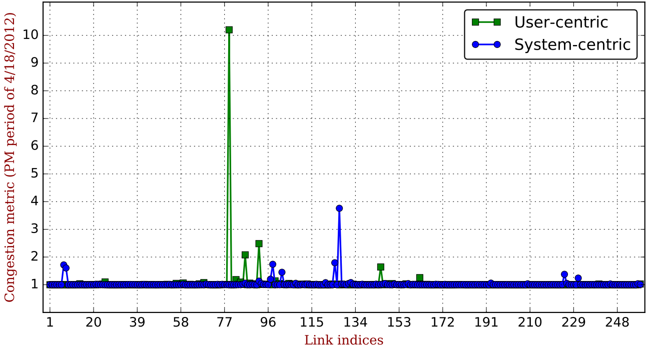
[2] https://github.com/jingzbu/InverseVIsTraffic, https://www.kaggle.com/jingzbu/ematransportation

Price-of-Anarchy (2012)



Road Congestion: Socially Optimal vs. User Optimal

"Spreading the traffic" results in:



Control and Interventions

1. Sensitivities: Where to intervene?
2. Socially optimal route recommendations: Can be shown that we can achieve the Socially Optimal solution through User Optimal actions if users use a properly modified congestion function!
    - Easier to incorporate in apps, even enforce with autonomous vehicles.
    - Take the driver "out of the picture."
3. Change demand! Congestion pricing and incentives!

Final remarks

- We have developed a new general framework for modeling driver behavior using data.
- Policy space: How to address traffic allocation issues and prevent NIMBY reactions?