



UNIVERSITY OF  
**ILLINOIS**  
URBANA - CHAMPAIGN

# Investigating Unintended Consequences of Automated Traffic Law Enforcement in Commuting

Chris Raymond-Bertrand

Presented on April 24th 2025



# Motivation

## Unproven efficacy

1. Reduce severity of crashes but not total number
2. Lack of human judgement
3. Legal issues?



## Positives?

### 1. Indiscriminately issues fines

However...

**... their placement is not devoid of bias.**

OAKBROOK TERRACE MAYOR RESIGNS AMID RED-LIGHT CAMERA PROBE

by JANUARY 23, 2020



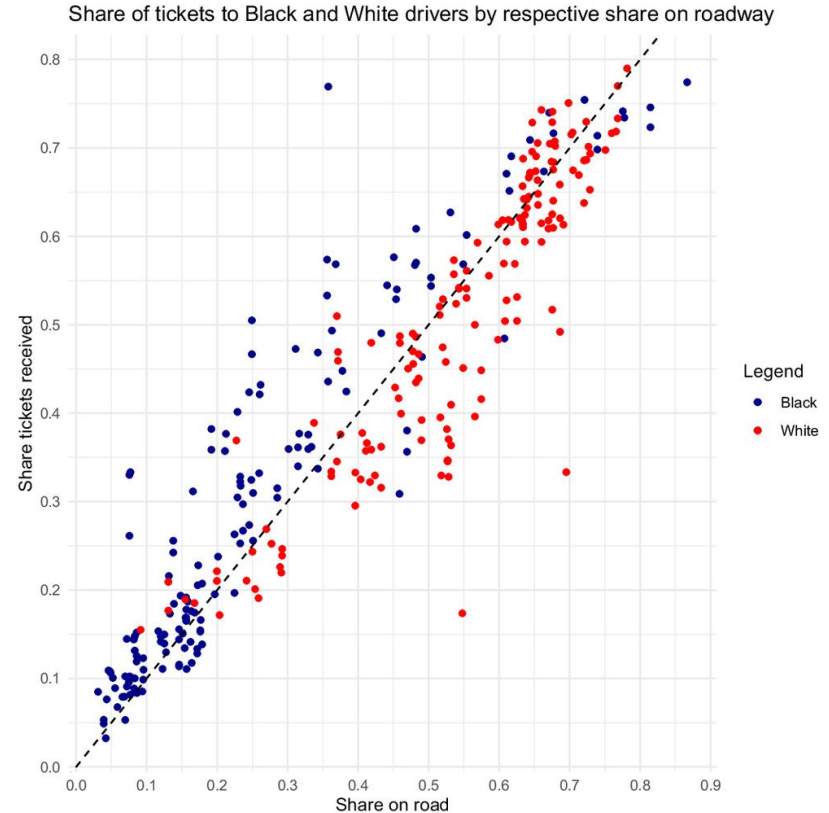
**Federal investigators have been digging into the political corruption surrounding red-light cameras, including a pair of the multi-million dollar traffic devices in Oakbrook Terrace.**

## Unequal outcomes

Black drivers get ticketed at a rate 10 (!!)  
times higher than white drivers.

Xu et al. (2024) proved that drivers from  
different demographic groups commit  
offenses at similar rates.

So clearly, something is at play. We  
theorize that the placement of the  
cameras is unfair.



## How do we quantify the impact of red light cameras?

### Time to avoid cameras

Find shortest path between two points, with and without avoiding the cameras, and measure difference in travel time.

### Number of cameras encountered

Find shortest path and count number of cameras we come across.



# Mathematical background

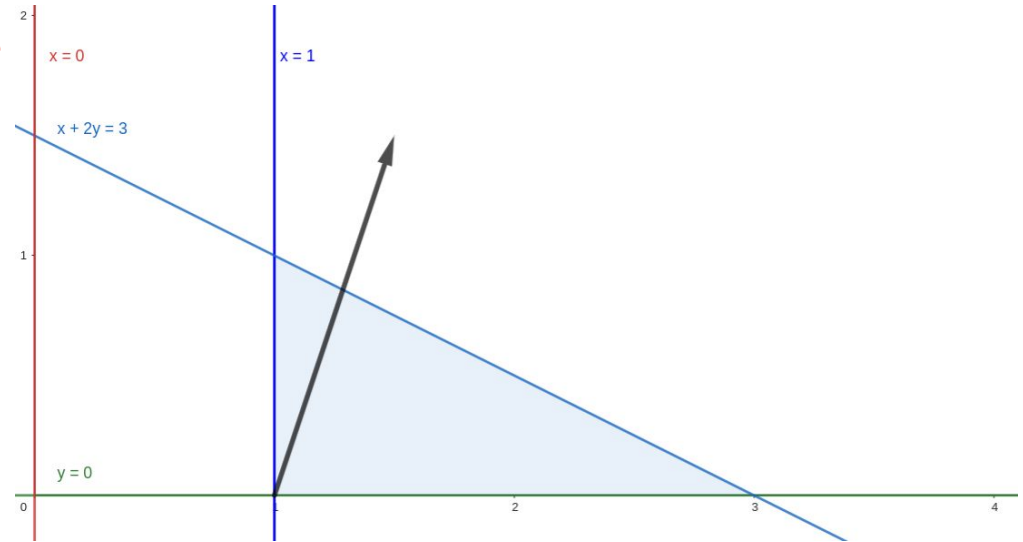
## Linear Programming/Optimization

Optimizing a linear function under linear constraints.

Find a vector  $\mathbf{x}$   
that maximizes  $\mathbf{c}^T \mathbf{x}$   
subject to  $A\mathbf{x} \leq \mathbf{b}$   
and  $\mathbf{x} \geq \mathbf{0}$ .

## Linear Programming Example

$$\begin{aligned} \max \quad & x_1 + 3x_2 \\ \text{subject to} \quad & x_1 + 2x_2 \leq 3 \\ & x_1 \geq 1 \\ & x_1, x_2 \geq 0 \end{aligned}$$

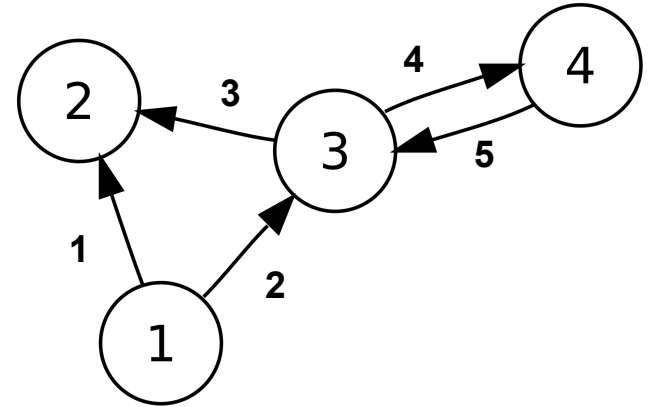


$$A = \begin{pmatrix} 1 & 1 \\ -1 & 0 \end{pmatrix}, \quad b = \begin{pmatrix} 3 \\ -1 \end{pmatrix}, \quad c = (1 \quad 3)$$

## Network theory

Define a network as a set of nodes connected by edges. These edges can be bi-directional (undirected) or unidirectional (directed).

We can define an incidence matrix, letting us know which edges and nodes are related.

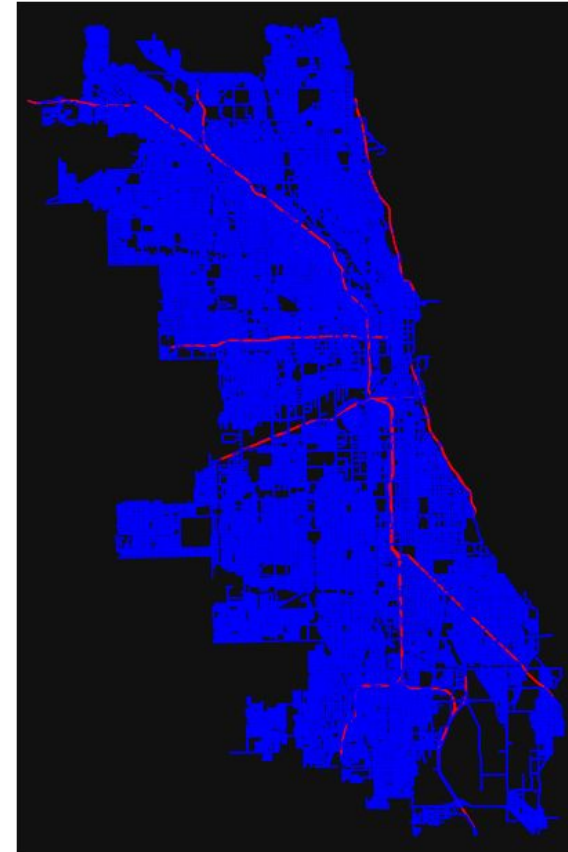


$$A = \begin{pmatrix} -1 & -1 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 \\ 0 & 1 & -1 & -1 & 1 \\ 0 & 0 & 0 & 1 & -1 \end{pmatrix}$$

## Combining the two

We can model the city of Chicago as a network of roads (edges) and intersections (nodes).

We can use linear programming to find the shortest path. We want to minimize the travel time while making sure we take a valid path.



$f_j = 1(0)$  if we do(don't) travel on road  $j$

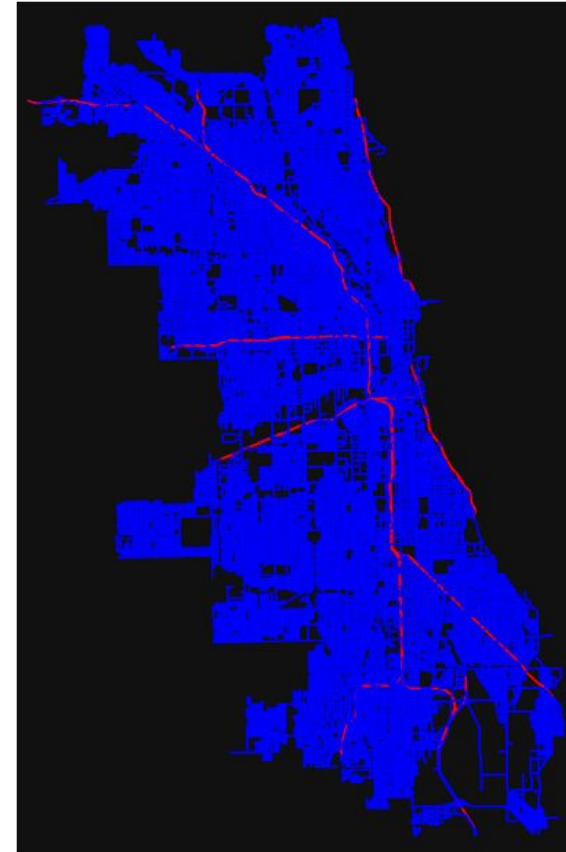
$w_j = \text{cost (time) to travel along road } j$

Flow balance principle says that:

- the starting node has one out-flowing edge
- the final node has one in-flowing edge
- every other node is either unvisited or has both an out-flowing and in-flowing edge

For every node  $i$

$$\sum_{j \in E} A_{ij} \cdot f_j = \begin{cases} -1 & \text{if } i \text{ is the starting node} \\ 1 & \text{if } i \text{ is the final node} \\ 0 & \text{otherwise} \end{cases}$$



## Final model

$$\min \sum_{j \in E} w_j \cdot f_j$$

subject to

$$\sum_{j \in E} A_{ij} \cdot f_j = \begin{cases} -1 & \text{if } i \text{ is the starting node} \\ 1 & \text{if } i \text{ is the final node} \\ 0 & \text{otherwise} \end{cases}$$

$$f_j = \begin{cases} 1 & \text{if we travel along road } j \\ 0 & \text{otherwise} \end{cases}$$







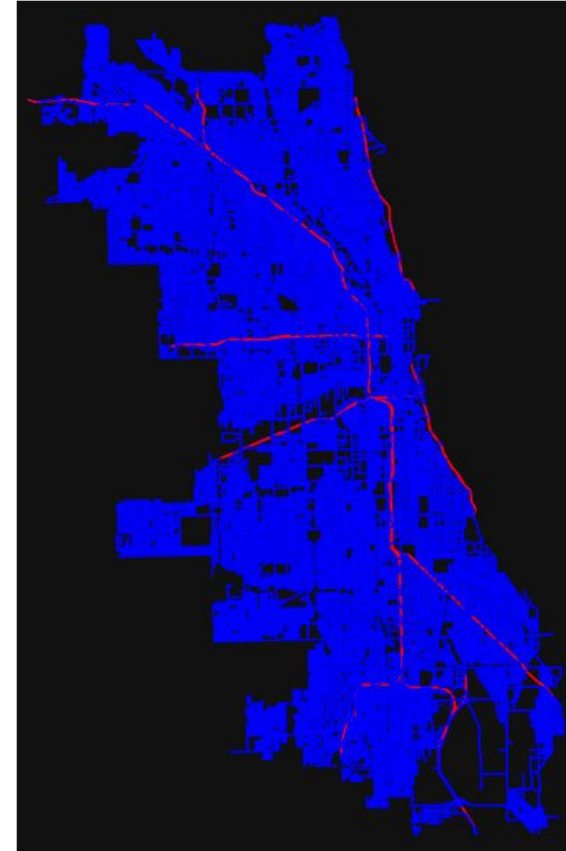
# Collecting data

## Chicago's street network

We use OpenStreetMap NetworkX (OSMNx), a Python library.

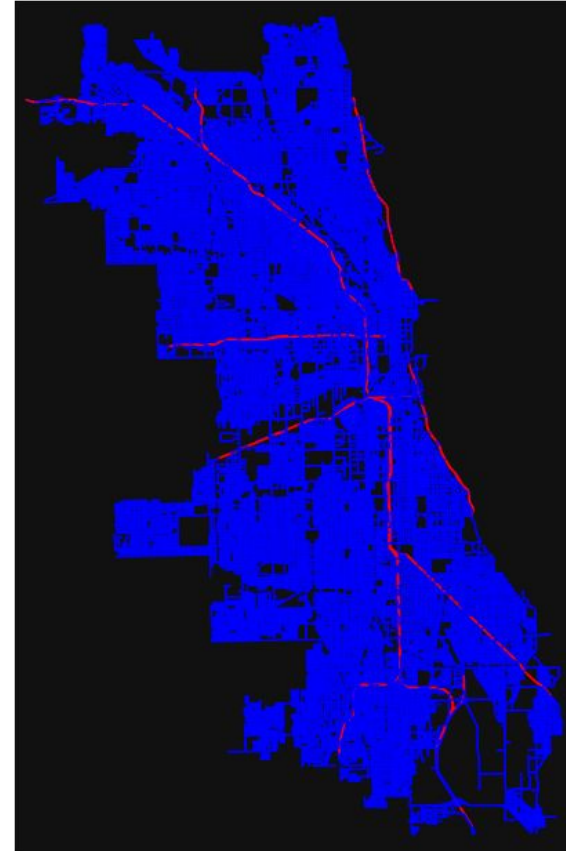
Contains:

- All roads and intersections
- Types of roads
- Time needed to travel



## Commuting patterns

We used the Chicago Metropolitan Agency for Planning (CMAP) **MyDailyTravel** dataset, which contains >10,000 data points.





# Applying our model

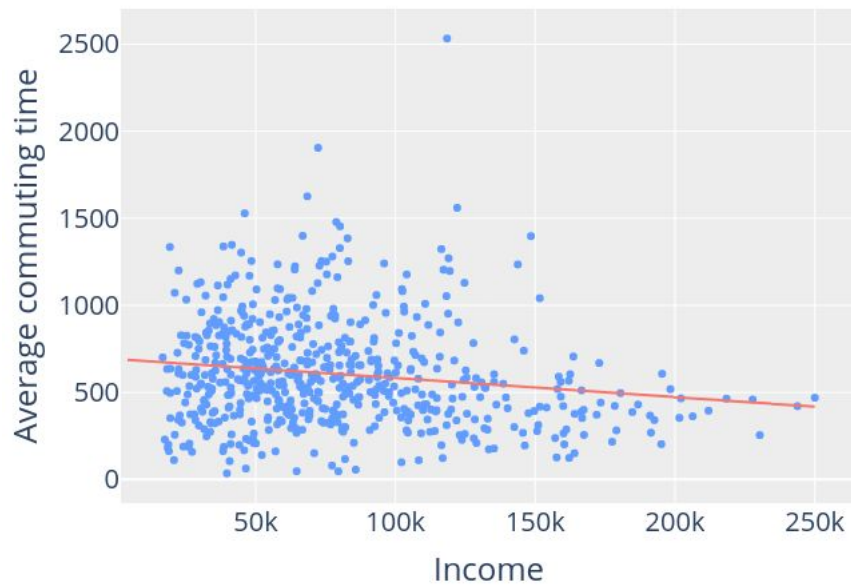
## ATLE and income levels

The longer your commute, the more cameras you will encounter.

$$\# \text{ cameras} = 0.001763 \cdot \text{Commute time}$$

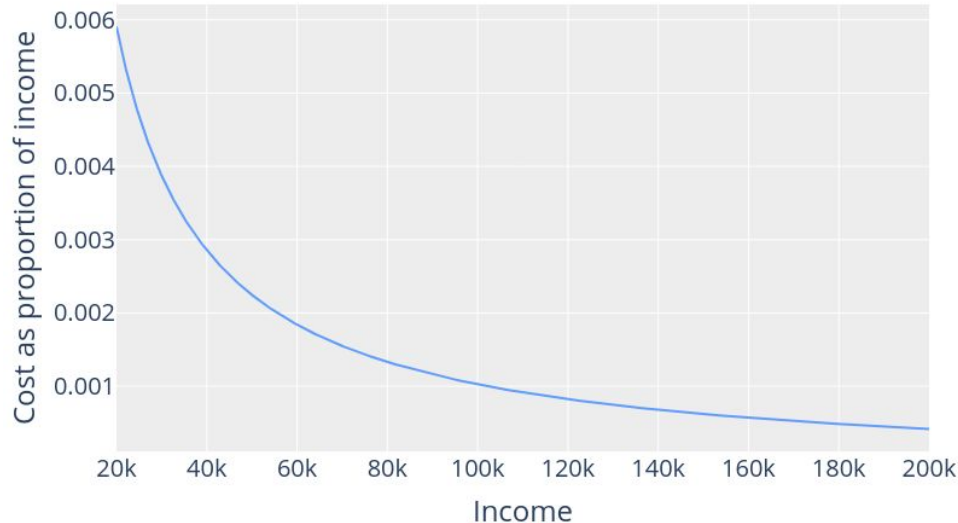
With  $p < 2e-16$ ,

$$\text{Commute time} = 691.9 - 0.001095 \cdot \text{Income}$$



## ATLE and income levels

Bringing those relationships together, we get



Proportionally, a household with \$30k annual income is impacted

**9.3** times

harder by ATLE than one making \$200k.