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Impact of mobility-based road pricing on transport networks

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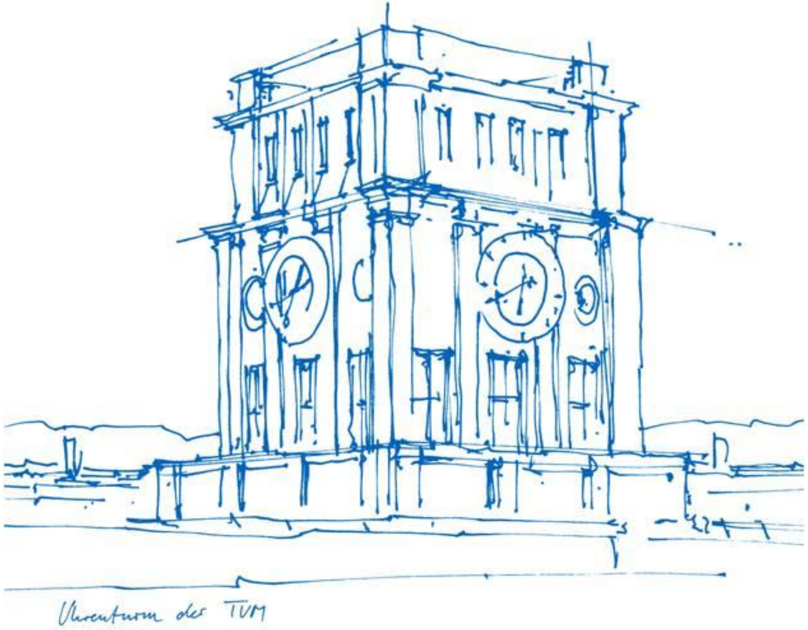
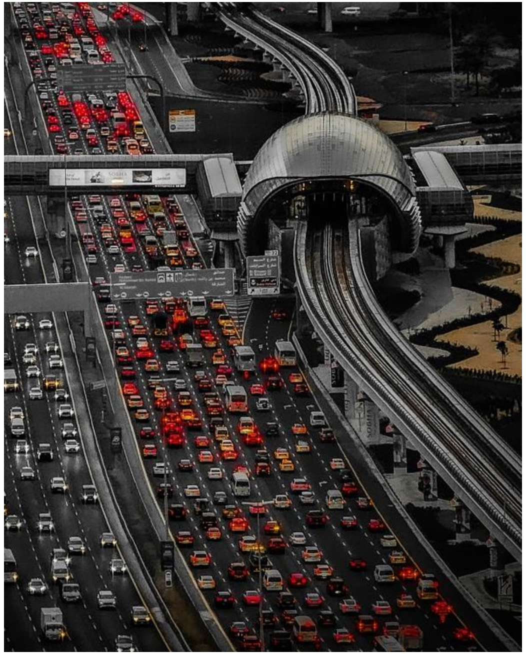


Motivation

- Electrification requires finding a **successor to the fuel excise tax**
- Increasing socio-economic and environmental **consequences of congestion** in urban areas
- Competition for urban space seems to be increasing, arguing for the communication and management of road space as a **finite resource**



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Road user charging

- Pricing jointly addresses congestion problems and provides revenue generation for the treasury

- Typical area-based pricing approaches
  - Pigouvian congestion pricing, i.e., marginal social cost pricing
  - Cordon or area-based pricing, e.g., London’s Congestion Charge
  - Distance- or duration-based pricing, e.g., Singapore’s ERP 2.0
  - Mobility-based pricing

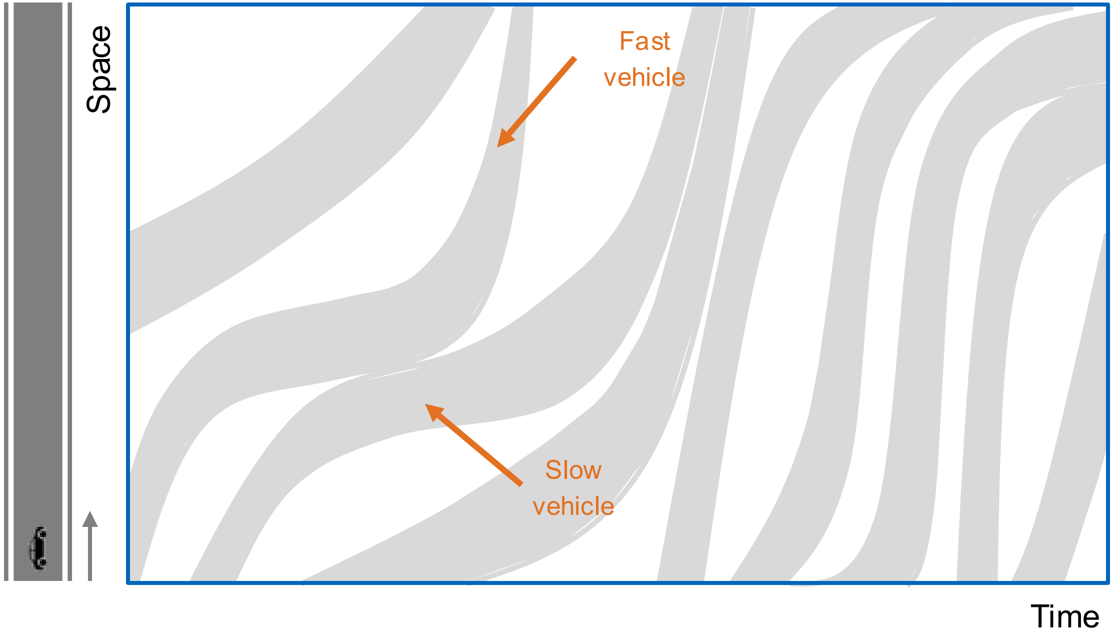
Measuring mobility

Common indicators

- Travel distance
- Travel time

Arguably, both **are incomplete measures** of mobility

- Vehicles consume spacetime
- Neither suggests a limited resource

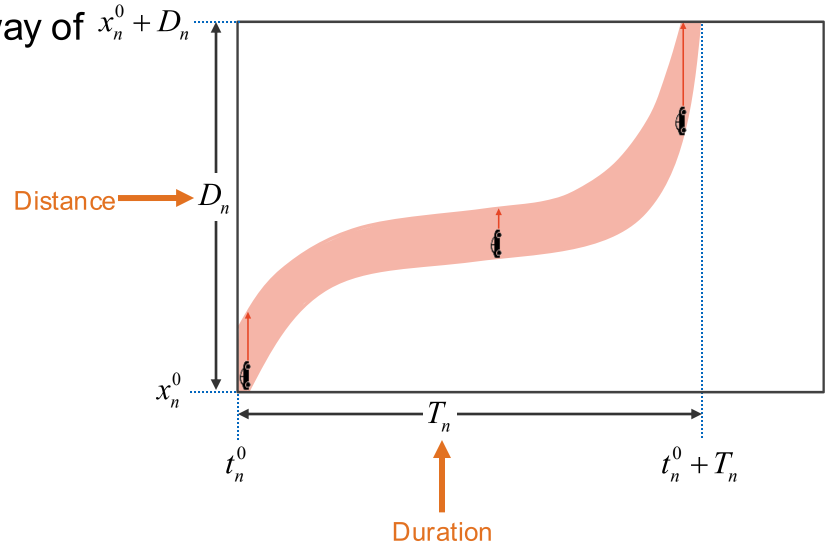


Consuming spacetime

- Deriving mobility consumption M_n from the safe headway of vehicle n using Pipes (1953) with λ_n minimum safe headway and τ_n reaction time of vehicle

$$M_n = \int_{t=t_n^0}^{t_n^0+T_n} h_n(t)dt$$

$$= \int_{t=t_n^0}^{t_n^0+T_n} \big(\lambda_n + \tau_n v_n(t)\big)dt = \lambda_n T_n + \tau_n D_n$$



- No trajectory data, only aggregated T_n and D_n
- Mobility-based charging raises a charge c_n proportional to mobility consumption

Bliemer et al. (2024)

Mobility consumption in networks

When considering all N vehicles in a network, the total mobility consumption M is obtained as follows

$$M = \sum_{n=1}^{N} M_n = \sum_{i=n}^{N} \lambda T_n + \tau D_n = \lambda \sum_{n=1}^{N} T_n + \tau \sum_{n=1}^{N} D_n$$

Networks are special

- Total available mobility potential equals to $\mathrm{L}\Delta T$ with L the total network length and ΔT the considered time window
- Mobility consumption **losses are unavoidable** due to traffic control

Research approach

Research question: how do the different discussed road user charging schemes impact the transport system?

Objective: perform a comparative analysis of different road user charging schemes to understand the impact of road user charging reform.

Considered schemes

- Fixed charging (fixed annual motor vehicle tax, no route choice impact)
- Distance-based charging
- Duration-based charging
- Congestion charging
- Mobility-based charging

Method

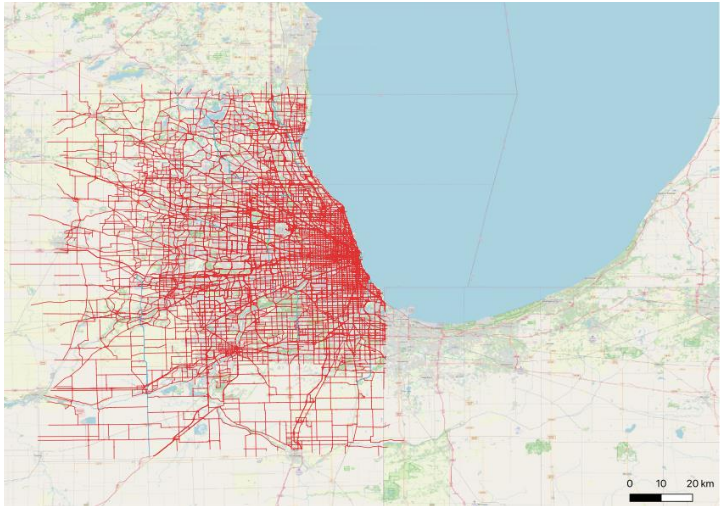
Simulating network outcomes

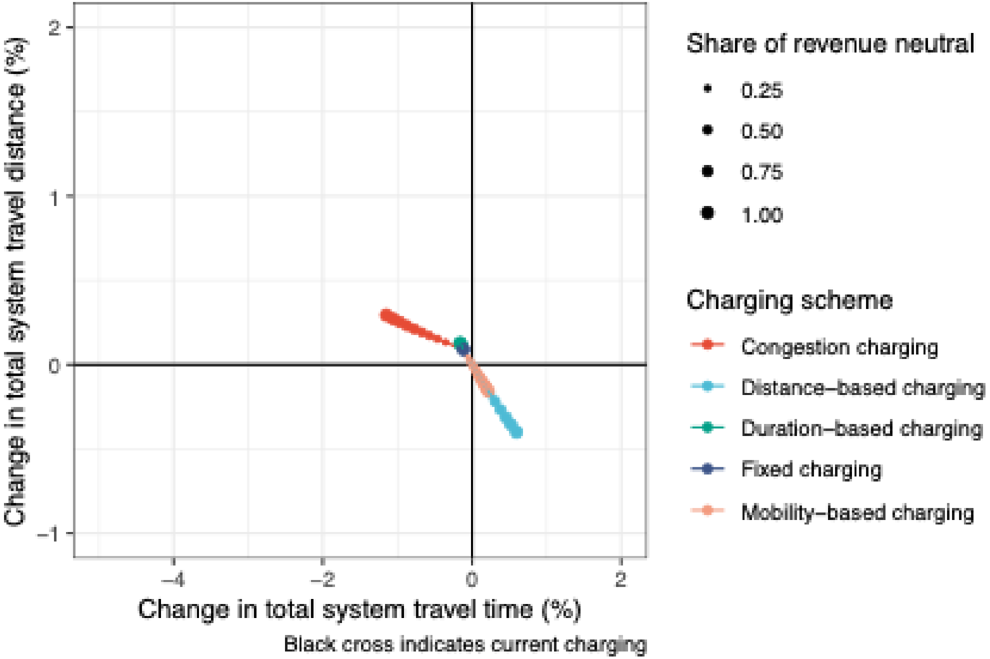
- Transport network analysis with static traffic assignment and inelastic demand
- Using an adopted Steve Boyles' TAP-B algorithm using Dial's bush-based *Algorithm B* (Dial 2006)
- Indicators: Changes in total system travel time and distance relative to current charging
- Distance-based user costs (without charges) are considered

Setting the road user charging parameters

- Three networks: Chicago, Munich, and Sydney
- Assuming revenue neutrality, i.e., the average driver does not pay more or less compared to today
- To compute the current revenue, we consider
  - Vehicle registration and/or use tax, i.e., billed annually
  - Fuel excise tax, i.e., billed per litre
  - Value added tax

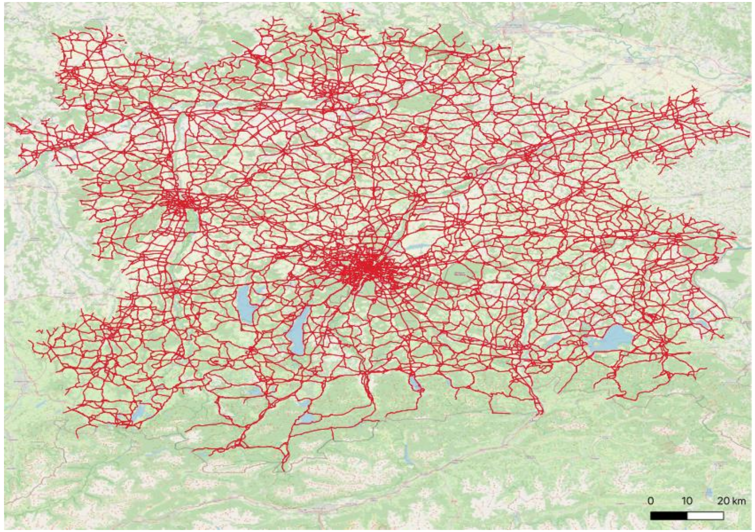
Chicago, Illinois

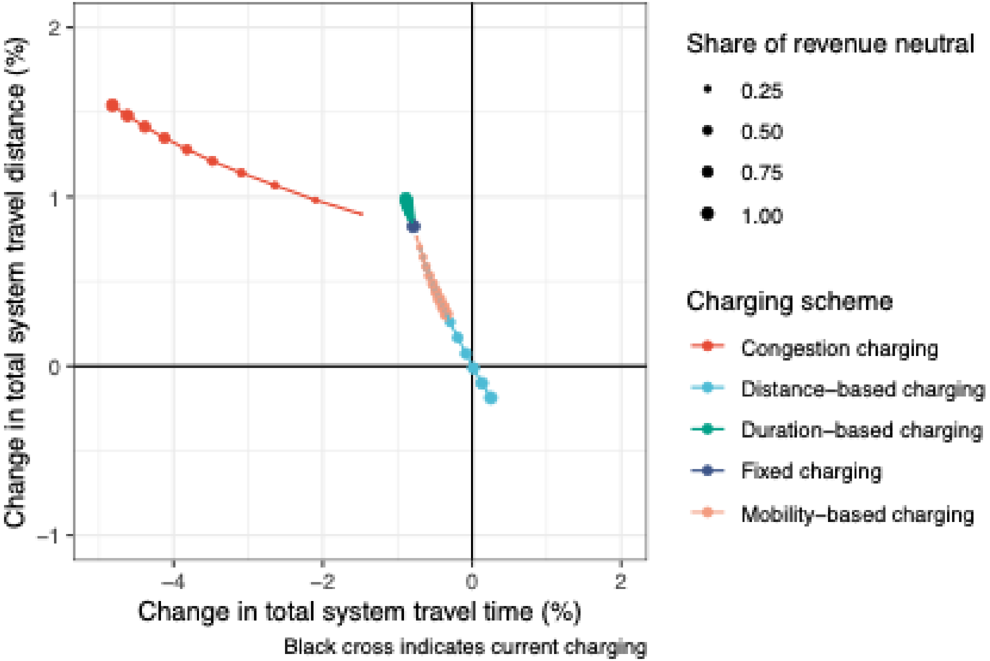




- Calibrated to peak-hour
- 1818347 trips
- 39 km/h average network speed (TomTom)
- Current tax revenue $0.57 per trip

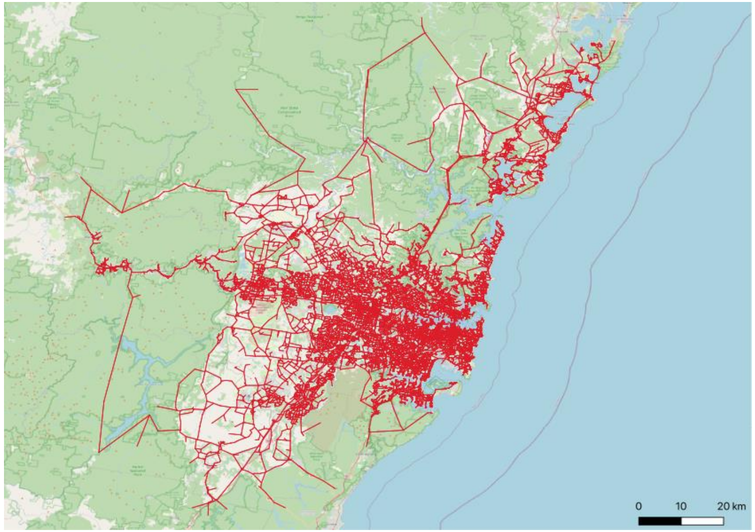
Munich, Germany

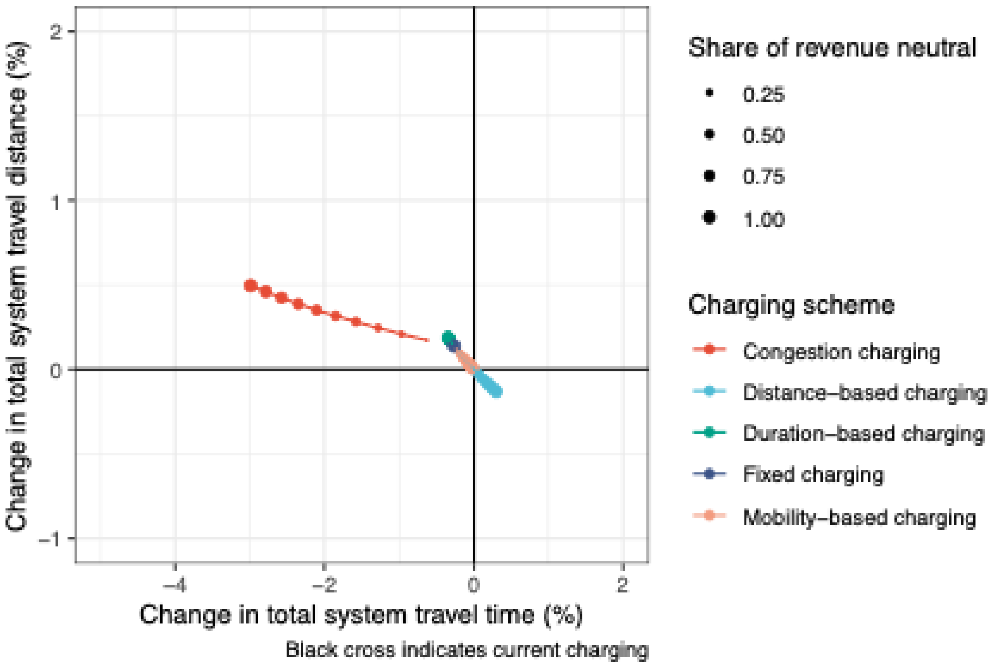




- Calibrated to peak-hour
- 2314385 trips
- 42km/h average network speed (TomTom)
- Current tax revenue €0.71 per trip

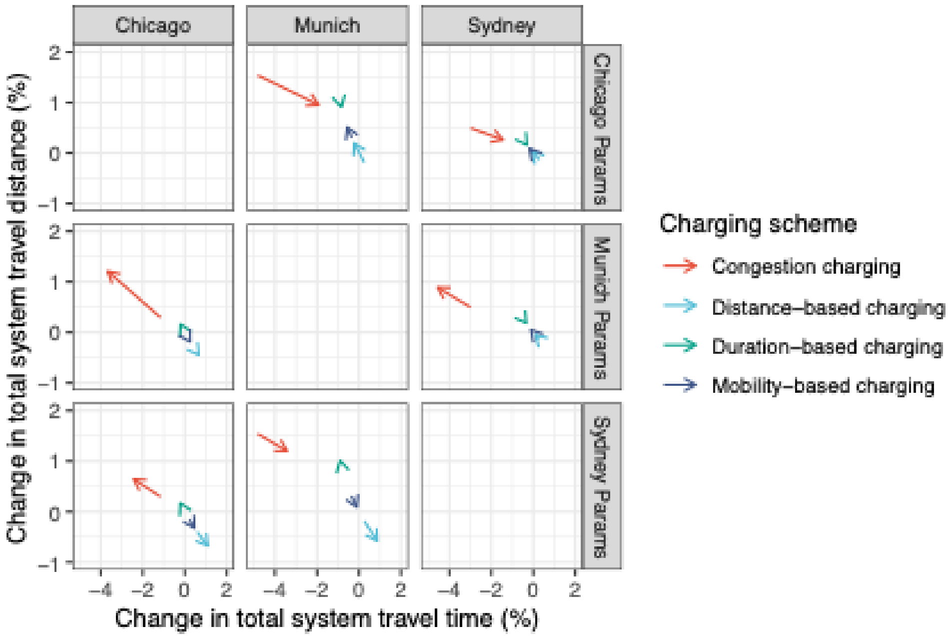
Sydney, Australia





- Calibrated to peak-hour
- 1698678 trips
- 32 km/h average network speed (TomTom)
- Current tax revenue $0.92 per trip

Counterfactuals: using another city's parameters



Summary

- Road user charging reform impacts network outcomes, but assuming revenue neutrality, changes are only about a few percent
  - More pronounced when more revenue must be recovered
  - Less likely that these changes impact trip generation

- Mobility-based charging between duration- and distance-based charging, incentivizing both dimensions in route choice

References

Bliemer, M.C., Loder, A. and Zheng, Z., 2024. A novel mobility consumption theory for road user charging. *Transportation Research Part B: Methodological*, *189*, p.102998.

Dial, R.B., 2006. A path-based user-equilibrium traffic assignment algorithm that obviates path storage and enumeration. *Transportation Research Part B: Methodological*, *40*, 917-936.