Reliability- and Median-based Identification of Toll Locations in a Connected Vehicle Context

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Motivation

- Road user fees address environmental and economic impacts of congestion.
- Efficacy is limited by time-varying demand and sparse spatial implementation.
- A connected-vehicle future promises:
  - On-board navigation with real-time rerouting
  - Electronic payment.
- These features enable the flexibility in tolling necessary to optimise system performance.

If spatially flexible dynamic tolling is possible, what’s the best way to target locations for tolls?

Data

Speeds and vehicle volumes from the California Department of Transportation’s Performance Measurement System (PeMS) are aggregated hourly for the months of Aug, Sept, Oct 2013. Converting speed to travel rates (time to travel one minute), each detector can be classified by its travel rate distribution (right). The maps below illustrate spatial patterns in two performance metrics: median speed and reliability (80th percentile travel time index (TTI)).

Methodology

Use freeway observations to see how speed- and reliability-based demand management might affect system performance

Identification

The first step is to identify locations with slow conditions. These locations are the targets of 3 levels of simulated tolls where observations matching the top 2%, 5% and 10% of demand are removed from the data. This process is repeated for locations flagged as unreliable. Each location can be slow, unreliable, neither or both.

Assessment

The post-toll distributions are reassessed using both the speed and reliability metrics. We compare the system impacts of the speed- and reliability-based tolls to better understand how and where we can achieve improvement.

Findings

- Initially 13.4% of the stations were slow and 18.2% were unreliable.
- None of the tolls visibly impact the shape of the distribution (see right).
- System median TT is robust to changes from tolls, but some tolls improve system reliability.
- A median-based toll reduces the fraction of slow stations from 13.4% to 12.0% which represents over 88,000 fewer vehicles/hr on slow links.
- A reliability-based toll decreases the fraction of unreliable stations from 18.2% to 14.2%, equivalent to over 210,000 fewer vehicles/hr experiencing unreliability. There is also a small improvement in the proportion of slow locations.

Conclusion

- Even huge tolls (10% reduction) have modest impacts.
- Reliability-based tolls result in improvements for more vehicles than median-based by reducing the fraction of locations that are slow and unreliable.
- Congested links are inherently popular, so targeting them has a big impact: 18.2% of stations are unreliable, but 23.0% of non-unique vehicles drive on these links.
- 10% demand reductions might require more than pricing.
- Effects would be stronger and more realistic if tolling targeted routes instead of links.

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