Markets for Transport

Eliminating Congestion through Scheduling, Routing, and Real-time Pricing

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• Global congestion costs $1 trillion/year
• Los Angeles congestion costs $23 billion/year
Cologne faces gridlock
CLOGGED STREETS, UNHAPPY TOURISTS

By Beth Teitell
GLOBE STAFF

Boston traffic has been driving locals berserk for years. But now it’s become so toxic that it’s taking aim at our guests — and threatening Boston and Cambridge’s $13 billion tourism industry.

Every major sightseeing firm contacted by the Globe has made or is mulling changes to deal with paralyzing congestion that never seems to end, and frustration is so intense that even PR types aren’t trying to sugarcoat the situation.

“It just stinks to tour Boston right now,” said Steven Grasso, president of North American Traveler, a North Reading-based travel-planning firm. One of his groups recently spent 35 minutes in a coach traveling from Faneuil Hall to the Boston Opera House — a 0.9-mile trip, according to Google Maps. “You can’t move,” he said.

As Bostonians know, no app in the world is capable of outsmarting local traffic. That leaves sightseeing companies to do what little is under their control.

They’re cutting major destinations from itineraries — who needs to see Harvard, Charlestown, the Seaport, or...
Transport market

• Open access
• Scheduled/routed transport
• Efficient congestion pricing

No congestion
The time is right

• Advances in mobile communications enable
  – Precise (to 1 cubic meter) location of vehicles
  – Easy communication of preferences, prices, schedules

• Advances in computers and markets enable efficient scheduling/routing and pricing of transport

*And case for innovation gets stronger each year*
Autonomous vehicles are here
Excellent topic for behavioral research

Complex trade-offs across time, roads and money
Drivers’ responses to market unknown
Lab and field experiments needed
An example of a highly controlled field study

Trade-offs in transport
Today’s transport is mostly free, but comes at the cost of uncertain congestion delays.

Our **market** puts a price on transport, but avoids delays (and improves throughput).

Both regimes cause some drivers to leave early, late, or not at all, or to switch roads ...
Behavioral research questions

Do *individuals* pick departure time and roads rationally?

- Simple competitive markets are known to work well (e.g., Smith 1962), but few lab studies look at behavior along different dimensions in competitive markets, such as time and space.
- Economic traffic experiments focus on simple, repeated coordination games without prices (Selten et al. 2007, Chmura/Pitz 2004a,b, Schneider/Weimann 2004, Rapoport et al. 2004), or include a simple toll (Gabuthy et al. 2006, Hartman 2009); almost all experiments induce identical driver preferences, inelastic demand and deterministic supply (but see Lopez 2017).

Are *markets* more efficient and acceptable than the status quo?
Which market design effectively promotes participation & acceptance?
There is enormous inertia—a tyranny of the status quo—in private and especially governmental arrangements. Only a crisis—actual or perceived—produces real change. When that crisis occurs, the actions that are taken depend on the ideas that are lying around. That, I believe, is our basic function [as economists]: to develop alternatives to existing policies, to keep them alive and available until the politically impossible becomes politically inevitable.
Our approach
From simple lab to complex natural settings

Simple lab setting
- Induced private values and time costs, simple road network
- Perfectly informed system operator vs optimization based on revealed preferences

Going to the field, step-by-step
- Actual supply and demand conditions, and cost estimates, from Singapore and L.A. to study the effectiveness of market mechanisms under ‘realistic’ conditions
- Real-time experiments to study trade-offs across time and money dimensions: subjects decide when to ‘drive’; working, eating etc. only allowed when not ‘driving’
- Actual driving decisions

Singapore as an ideal test-bed in the field
Privacy
Equity

vs

vs
Market objectives

• Efficiency
• Transparency
• Simplicity
• Fairness

*Draw on best practice from existing time and locational markets*
Key market principle: open access

- Transport network is open to all
- Nondiscriminatory terms
- Network capacity cannot be withheld

$\Rightarrow$ Efficient congestion pricing

- Basis for restructured electricity markets in US, Europe, ...
Open access transport network (Independent System Operator)

Integrated wholesale and retail market

Users/vehicles

Singapore market model
Open access transport network (Independent System Operator)

Wholesale market

Service providers

Users/vehicles

Retail market

Same market model as electricity successfully operating for two decades
Players

• Independent System Operator (ISO)
  – Runs market

• ISO or service providers
  – Develop user app for expression of demand
  – Aggregate user demand
  – Guide user (scheduling/routing)
  – Establish user plans and settle payment

• Users
  – Provide fundamental demand for road use
Product design

• Slot on congested road segment at particular time (e.g. 10 minute time interval)
Important features of setting

• Limited number of congested road segments
  – Bridges, tunnels, and other bottlenecks
• Congested segments are highly predictable
• Demand *does* respond to price even close to real time
  – Time shifters: shift transport to less congested time
  – Route shifters: shift route to less congested route
  – Mode shifters: take train, bus, bike or work-at-home
How today’s apps would change
GOOGLE TRAVEL TIMES

Home
Dahlonega Rd
1 min

Work
I-495 N
30 min
$3.42↑

JUST NOW

T-Mobile Wi-Fi
2:21 PM

Route options

Avoid highways

Avoid tolls

Avoid ferries
Value of time $75/hour Edit
Vehicle: MD 012 ABC Edit

Remember settings
Multiple opportunities to trade

• Real time (10 minutes)
  – Apps redirect traffic given preferences and prices

• Daily
  – Service providers estimate demand for each congested road segment in each 10 minute interval

• Monthly
  – Service providers estimate demand for month

*Forward markets are financial; real time is physical*
Sequence of auctions

- Multiple opportunities to trade
  - Reduces risk of service provider
  - Facilitates planning of service provider
  - Provides price transparency
  - Mitigates market power
Why wholesale market model?

- Allows relatively easy entry as service provider
- Competition among service providers promotes innovation
  - Understanding user demands
  - Translating user demands into bids in market
  - Developing forward trading strategies to mitigate risk
- But in city-states like Singapore with history of innovation system operator could play service provider role too
All markets use single-price auction

All markets use single-price auction

All markets use single-price auction
Auction design

- Uniform-price auction for each product
- Wholesale preferences expressed as piecewise-linear strictly-decreasing demand curves
  - Consistent with underlying preferences
  - Unique clearing prices and quantities
Current Published Supply Curve for Manhattan (Peak)

Select a product to view its supply curve calculated from the relative supply curve currently in the system.
Sample demand for bidder

Manhattan (peak) monthly

<table>
<thead>
<tr>
<th>Manhattan (Peak)</th>
<th>At</th>
<th>GB hold</th>
<th>GB/h</th>
<th>Add</th>
<th>Cancel</th>
</tr>
</thead>
</table>

### Future Rounds

<table>
<thead>
<tr>
<th>Price</th>
<th>Quantity</th>
<th>Change in Quantity</th>
<th>Commitment (180 hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$9.00/GB</td>
<td>-1,000,000 GB/h</td>
<td>-3,000,000 GB/h</td>
<td>-$4,860,000</td>
</tr>
<tr>
<td>$7.00/GB</td>
<td>-200,000 GB/h</td>
<td>-2,200,000 GB/h</td>
<td>-$2,772,000</td>
</tr>
<tr>
<td>$6.00/GB</td>
<td>500,000 GB/h</td>
<td>-1,500,000 GB/h</td>
<td>-$1,620,000</td>
</tr>
<tr>
<td>$5.00/GB</td>
<td>2,000,000 GB/h</td>
<td>0,000 GB/h</td>
<td>$0</td>
</tr>
</tbody>
</table>

### Current Round

<table>
<thead>
<tr>
<th>Price</th>
<th>Quantity</th>
<th>Change in Quantity</th>
<th>Commitment (180 hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$4.00/GB</td>
<td>2,083.333 GB/h</td>
<td>83.333 GB/h</td>
<td>$60,000</td>
</tr>
<tr>
<td>$3.80/GB</td>
<td>2,100,000 GB/h</td>
<td>100,000 GB/h</td>
<td>$68,400</td>
</tr>
<tr>
<td>$3.50/GB</td>
<td>2,300,000 GB/h</td>
<td>300,000 GB/h</td>
<td>$189,000</td>
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</tbody>
</table>

### Past Rounds

<table>
<thead>
<tr>
<th>Price</th>
<th>Quantity</th>
<th>Change in Quantity</th>
<th>Commitment (180 hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$3.00/GB</td>
<td>2,400,000 GB/h</td>
<td>400,000 GB/h</td>
<td>$216,000</td>
</tr>
<tr>
<td>$2.50/GB</td>
<td>2,500,000 GB/h</td>
<td>500,000 GB/h</td>
<td>$225,000</td>
</tr>
<tr>
<td>$2.00/GB</td>
<td>2,666,667 GB/h</td>
<td>666,667 GB/h</td>
<td>$240,000</td>
</tr>
</tbody>
</table>

### Price Floor

| $1.00/GB | 3,000,000 GB/h | 1,000,000 GB/h | $180,000 |
## ForwardTransport, Inc. ... *lock in prices and drive with confidence!*

<table>
<thead>
<tr>
<th>Type</th>
<th>Mon</th>
<th>Tue</th>
<th>Wed</th>
<th>Thu</th>
<th>Fri</th>
<th>Sat</th>
<th>Sun</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily trip</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Round trip</th>
<th>One way</th>
<th>Multi-stop</th>
<th>Vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home</td>
<td>Work</td>
<td>MD 0123</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Begin</th>
<th>End</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wed, 1 Nov 2017</td>
<td>Thu, 30 Nov 2017</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Depart</th>
<th>Arrive</th>
<th>Cost per trip</th>
<th>$ 3.76</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home to Work</td>
<td>8:00am</td>
<td>8:28am</td>
<td></td>
</tr>
<tr>
<td>Work to Home</td>
<td>5:00pm</td>
<td>5:28pm</td>
<td></td>
</tr>
</tbody>
</table>

### Alternatives and Price Change

<table>
<thead>
<tr>
<th>Later</th>
<th>Earlier</th>
</tr>
</thead>
<tbody>
<tr>
<td>+10 min</td>
<td>$ 0.45</td>
</tr>
<tr>
<td>+20 min</td>
<td>$ (0.20)</td>
</tr>
<tr>
<td>+30 min</td>
<td>$ (0.46)</td>
</tr>
<tr>
<td>+40 min</td>
<td>$ (1.11)</td>
</tr>
<tr>
<td>+50 min</td>
<td>$ (1.21)</td>
</tr>
<tr>
<td>+60 min</td>
<td>$ (1.40)</td>
</tr>
<tr>
<td>+70 min</td>
<td>$ (1.56)</td>
</tr>
</tbody>
</table>

| +10 min        | $ 0.32       |
| +20 min        | $ (0.33)     |
| +30 min        | $ (0.59)     |
| +40 min        | $ (1.24)     |
| +50 min        | $ (1.34)     |
| +60 min        | $ (1.53)     |
| +70 min        | $ (1.69)     |

| +10 min        | $ 0.32       |
| +20 min        | $ (0.33)     |
| +30 min        | $ (0.59)     |
| +40 min        | $ (1.24)     |
| +50 min        | $ (1.34)     |
| +60 min        | $ (1.53)     |
| +70 min        | $ (1.69)     |

### Add to Cart
Investment

• Transparent pricing provides detailed information for network investment
• Revenues provide essential funds for investment
Independent system operator

• Non-profit entity set up with simple mission
  “To serve the public by operating a reliable and efficient market for transport”

• Analogous to system or grid operator in wholesale electricity markets
Tasks of independent system operator

- Qualifies market participants and establishes any limits on each participant’s bidding activities
- Reveals the supply curves for the open access network
- Conducts the weekly auction
- Conducts the daily auctions
- Conducts the real-time auctions
- Operates the open access market
- Settles all transactions on a monthly basis consistent with market rules and supply and demand realizations
- Provides information on market performance to market participants and the market monitor
- Improves the market as problems are identified
- May serve as default service provider
Governance of market

Transport regulator

Board of independent system operator

Includes independent directors and directors affiliated with stakeholders

Independent system operator

Independent market monitor
Conclusion

• Assures transport network is used efficiently
• Eliminates congestion through scheduling/routing and congestion pricing
• Transparent pricing motivates network investment and provides much needed funds