It pays to do the right thing: Incentive mechanisms for decongesting roads

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N.S. Rama and many other Infoscions
Societal networks

- Societal networks: Networks concerned with societal processes

Transportation networks – congestion

Electricity networks – generation and consumption

Recycling networks

Societal networks $\equiv$ Resources $+$ Technological mechanisms $+$ Human actions

Better technology

Incentivize people to do the right things
Cost of congestion

- Fuel and time costs in 2005, US-wide
  A. $ 8 million
  B. $ 80 million
  C. $ 8 billion
  D. $ 80 billion

- US auto bailout: $ 25 billion
- Stimulus package for Wall Street: $ 700 billion
Fuel cost

• Fuel wasted in urban U.S. in 2005
  A. 3 million gallons
  B. 30 million gallons
  C. 3 billion gallons
  D. 30 billion gallons

• Equal to fuel consumed in all of the U.S. in 6 days!
  – 2006 data
Current methods: Charge drivers who enter “congested zone”
  – E.g. London, Singapore, Stockholm
  – Effective, but viewed as “yet another tax”

Our proposal: Charge congestors, pay decongestors
  – Put “intelligence” in vehicles, not on road
  – Deploy incrementally, no need for every one to start on day one
• Small good deeds don’t carry adequate rewards, so they aren’t performed
  – A system, which pools individual rewards, but pays out a few large sums through raffles may carry adequate incentives

• In games with low stakes, players are more risk seeking

• Two envelope game:
  – Envelope 1: $10
  – Envelope 2: $110 with 10% chance, $0 else (Ave = $11)
  – Q: Which will you choose?

• Version 2:
  – Envelope 1: $1
  – Envelope 2: $11 with 10% chance, $0 else

• Theorem: If you choose Envelope 2 in Version 1, you will also choose it in Version 2
More precisely

- Let $U(.)$ be a concave utility function with $U(0)=0$, and assume one of the following two conditions holds:
  1. $-xU''(x)/U'(x)\geq 1$ (This is the well known Relative Risk Aversion function)
  2. $xU'(x)/U(x)$ is a monotonic decreasing function.

- If $X \geq 0$ is a random variable representing payoff, then for $0<\delta<1$, $E[U(X)]-U(\delta E(X)) \geq 0$ for sufficiently small $E(X)$. 
Experimenting with Societal Networks

• Transportation networks
  – The INSTANT project
  – Congestion at Stanford, etc

• Recycling: Freshman seminar in Spr 2010
The INSTANT project

- The INSTANT (Infosys-Stanford Traffic) project is a pilot study of using an incentive mechanism to decongest road traffic
Bus data

- 240 buses, 120 starting points, 4 major routes
- Data from January 2005 to June 2008
  - Pick up, drop off times; bus occupancies

<table>
<thead>
<tr>
<th>Bus #</th>
<th>Pick-up Time</th>
<th>Drop Time</th>
<th>Pick-up Point</th>
<th>Cap</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>54</td>
<td>700</td>
<td>732</td>
<td>JAYA NAGAR 4TH BLOCK /18TH MAIN</td>
<td>49</td>
<td>61</td>
<td>12</td>
<td></td>
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<tr>
<td>56</td>
<td>650</td>
<td>738</td>
<td>NANDIGARDEN / R.V.DENTAL COLLEGE</td>
<td>49</td>
<td>45</td>
<td>4</td>
<td></td>
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<tr>
<td>57</td>
<td>700</td>
<td>752</td>
<td>JAMBUSAVARIDINNE/R.V.DENTAL</td>
<td>49</td>
<td>38</td>
<td>11</td>
<td></td>
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<tr>
<td>60</td>
<td>700</td>
<td>745</td>
<td>GOTTEGERI / B.G.PARKING LOT</td>
<td>49</td>
<td>28</td>
<td>21</td>
<td></td>
</tr>
</tbody>
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A - Occupancy  
B - Standing  
C - Empty Seats
Bus occupancy: Early vs late
June 2008;  Bus capacity = 49

Bus occupancy: Early vs late
June 2008;  Bus capacity = 49

- Early pick-up (prior to 7:15 AM)
- Late pick-up (after 7:15 AM)

Over capacity
Journey times from Jayanagar
• Warning: Portions of this material may be disturbing for some viewers. Discretion is advised.
Morning GPS trace:
Jayanagar to Infy

6:15 AM

8:15 AM
Morning GPS trace:
Jayanagar to Infy

Commute time: 29 mins.

Commute time: 82 mins.
The incentive mechanism

At a Glance

Commuter’s working day begins

Arrival (swipe-in) time

Arrival before 8.00 AM
- Earn 1.5 credits
- Incentive mechanism
- Rewards given weekly

Arrival between 8.00 – 8.30 AM
- Earn 1 credit

Arrival after 8.30 AM
- No credit
An illustration

- $2 \times 12,000 \ (20)$
- $4 \times 6,000 \ (12)$
- $14 \times 2,000 \ (7)$
- $58 \times 500 \ (3)$
Results
Average morning bus commute time (and total person-hrs saved)

- Pilot launched: 100 person-hrs
- Pilot ended:
  - Apr '09 (week 1-2): 2000 p-hrs
  - Apr '09 (week 3-4): 2200 p-hrs
  - May '09: 2400 p-hrs
  - Jun '09: 2000 p-hrs

<table>
<thead>
<tr>
<th>Month</th>
<th>Average morning bus commute time in minutes</th>
</tr>
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<tbody>
<tr>
<td>Sep '08</td>
<td>65</td>
</tr>
<tr>
<td>Oct '08</td>
<td>65</td>
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<tr>
<td>Nov '08</td>
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<td>Dec '08</td>
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<td>Jan '09</td>
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<td>Feb '09</td>
<td>65</td>
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<td>Mar '09</td>
<td>65</td>
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<tr>
<td>Apr '09 (week 1-2)</td>
<td>65</td>
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<tr>
<td>Apr '09 (week 3-4)</td>
<td>65</td>
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<td>May '09</td>
<td>65</td>
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<tr>
<td>Jun '09</td>
<td>65</td>
</tr>
</tbody>
</table>

Person-hrs saved:
- 1400 p-hrs
- 2000 p-hrs
- 2200 p-hrs
- 2400 p-hrs
- 2600 p-hrs
- 2300 p-hrs
- 2000 p-hrs
Summary of INSTANT

- Reduction in commute times: at least 80 mins each day
- More comfortable rides
- Savings in fuel cost: Rs. 15,000 per day
- Reduction in bus fleet size: 8 buses
- Infosys will launch INSTANT at all 8 of their India offices
At Stanford

- Parking at Stanford: Reduce peak hour trips
Stanford congestion

- Agreement with Santa Clara County in 2001
  - Morning inbound limit = 3,319 vehicles, + 1% tolerance
  - Evening outbound limit = 3,446 vehicles, + 1% tolerance
Our proposal

- In collaboration with P&TS
  - RFID parking stickers
  - Incentive mechanism allows commuters to earn back part of their parking fees
  - We’ll have both deterministic and random payoffs
Formal structures

• Under formation: Institute/center on Societal Networks
• Scientific Board
  – Kenneth Arrow, Stanford
    • Joan Kenney Professor of Economics and Professor of Operations Research
    • Convening Lead Author: Intergovernmental Panel on Climate Change
  – Frank Kelly, Cambridge
    • Professor of the Mathematics of Systems, Master of Christ’s College
    • Chief Scientific Adviser to the UK Department for Transportation, 2003--2006
  – Pravin Varaiya, Berkeley
    • Nortel Networks Distinguished Professor, EECS
    • Director of California PATH Program, 1994--1997
  – Hal Varian, Berkeley/Google
    • Professor: School of Information, Haas School of Business, Dept of Economics
    • Chief Economist, Google