WHY LISTEN TO ME?

➔ Researcher, Practitioner, and Consultant in Priced Express Lanes since 1994
  ▪ 21 states
  ▪ 3 countries
  ▪ 118 projects
  ▪ 16 publications
TODAY’S DISCUSSION

- Freeway Tolling to Manage Congestion
- Where / How Has the Concept Been Used
- Policy, Design, and Operations Options
- When Things Don’t Go Right
- Lessons and Trends
WHAT’S THE POINT OF FREEWAY TOLLING?
#1 RAISE REVENUE

- Drive More, Use Less Gas
- Net Decline in Gas Tax Revenue Corresponds with Fuel Efficiency Increase Since 2005
#2 SOLVE THE ECONOMICS OF CONGESTION

Congestion is an imbalance between:

- Supply (highway lanes)
- Demand (highway travel)

Equilibrium where Supply and Demand are in balance
ECONOMICS OF CONGESTION

Congestion is an imbalance between:
- Supply (highway lanes)
- Demand (highway travel)

Unlimited demand yields overconsumption of supply
- Demand limited by fuel consumption, not location and time of use

Outcome is economic scarcity
DEALING WITH SCARCITY

3 Options for Dealing with Scarcity

- Increase Capacity
- Reduce Demand
- Control Access
DEALING WITH SCARCITY

Build More Lanes
- Congestion relief is temporary
- Does not fix the fundamental imbalance
- Widening costs are expensive

Reduce Demand
- Yields rationing and trip avoidance
- Requires viable alternatives
- Impedes economic productivity

Control Access
- Does nothing for growth
- Shifts more trips to arterials
AVOIDING CONGESTION

→ Requires a fundamental commitment to manage roadway capacity to avoid traffic flow breakdowns.
CONGESTION IS THE RESULT OF FLOW BREAKDOWN

→ **Predictable conditions**
  - **Bottlenecks** at known locations
    - Ramp merges, grades, weaving points, lane constrictions, bridges, etc.
  - **Speed differentials** between vehicles

→ **Unpredictable conditions**
  - **Driver behavior** that slows traffic, such as rubber necking or sudden braking
  - **Spikes in traffic** that yield short periods of high density flow
Flow breaks down at 1800 – 2000 vehicles per hour per lane
EXAMPLE OF FLOW BREAKDOWN
EXAMPLE OF FLOW BREAKDOWN
WHY SHOULD WE USE TOLLING?

→ **Generates Revenue**
  - Afford more than we could otherwise build and maintain

→ **Meters Traffic**
  - Higher travel speeds accrue in medium and (especially) long term
  - Pricing more efficient than signalization or rationing

You Don’t Need a Toll to Meter
I-70 (Colorado) meters traffic through mainline traffic signals.
FREEWAY TOLLING COMBINES ALL THREE

→ Application
  - Expands capacity
  - Shifts demand
  - Uses Pricing

→ Outcome
  - Congestion-free lanes
  - Safety & Reliability
  - Long term Return on Investment

I-495, Virginia
FREEWAY TOLLING MORE EFFICIENT

- Use of pricing meters traffic in order to prevent breakdown into congested conditions
FREEWAY TOLLING IN PRACTICE
TOLLED EXPRESS LANES: 2003

SR 91 Express
I-15 FasTrak
US 290 QuickRide
I-10 QuickRide
TOLLED EXPRESS LANES: 2013

- SR 167 HOT Lanes
- I-85 Express
- SR 237 / I-880 Express
- I-15 Express
- I-680 Express
- I-10 Metro Express
- I-110 Metro Express
- SR 91 Express
- I-15 San Diego
- I-394 MnPASS
- I-35W MnPASS
- I-25 Express
- SR 91 Express
- I-85 Express
- I-495 Express
- I-45 North
- US 290 Northwest
- US 59 South
- US 59 North
- I-10 Katy Freeway
- I-45 South
- I-10 Metro Express
- US 59 North
- I-95 Express
- I-45 North

Map showing the locations of tolled express lanes in 2013.
TOLLED EXPRESS LANES: 2016

- I-405 Express Toll
- SR 167 HOT Lanes
- I-15 Express
- I-580 Express
- I-680 Express
- SR 237 / I-880 Express
- I-110 Metro Express
- SR 91 Express
- SR 91 RCTC
- I-15 San Diego
- Loop 375
- US 36 Express
- I-25 Express
- I-25 Reversible
- I-70 Mountain
- DFW Connector
- North Tarrant Express
- SR 91 RCTC
- I-45 North
- US 290 Northwest
- US 59 South
- I-45 South
- I-10 Katy Freeway
- I-635 LBJ Managed
- US 59 North
- I-595 Express
- I-95 Express
- I-495 Express
- I-85 Express
- I-595 Express
- I-95 Express
- I-405 Express Toll
- SR 167 HOT Lanes
- I-15 Express
- I-580 Express
- I-680 Express
- SR 237 / I-880 Express
- I-110 Metro Express
- SR 91 Express
- SR 91 RCTC
- I-15 San Diego
- Loop 375
- US 36 Express
- I-25 Express
- I-25 Reversible
- I-70 Mountain
- DFW Connector
- North Tarrant Express
- SR 91 RCTC
- I-45 North
- US 290 Northwest
- US 59 South
- I-45 South
- I-10 Katy Freeway
- I-635 LBJ Managed
- US 59 North
- I-595 Express
- I-95 Express
- I-495 Express
- I-85 Express
- I-595 Express
- I-95 Express
RAPID GROWTH IN TOLLED EXPRESS LANES

Almost doubling the total lane miles in the next five years

Cumulative Mileage of HOT Lanes in United States

Graphic Source:
Prof. David Levinson, University of Minnesota, June 15, 2015.
ALREADY IN SECOND GENERATION

I-15 San Diego, 2003

I-15 San Diego, 2013

I-10 Houston, 1999

I-10 Houston, 2013
POLICY, DESIGN, AND OPERATIONS
NOT ALL FACILITIES ARE THE SAME

Convert HOV Lanes
- Overused HOV
  - I-85 Atlanta
  - I-405 Seattle
- Underused HOV
  - I-25 Denver
  - I-15 Salt Lake City
  - SR-167 Seattle
  - I-394 Minneapolis

Build New Lanes
- Convert + Build
  - I-15 San Diego
  - I-95 Miami
  - I-495 Virginia
  - I-35W Minneapolis
  - I-10 Houston
  - I-635 Dallas
- Build Only
  - SR-91 Orange County
  - I-595 Ft. Lauderdale
  - North Tarrant Express Dallas
  - DFW Connector Dallas

Anticipate More Benefits
Anticipate Less Benefits
INITIAL LANES WERE PHYSICALLY SEPARATED
CONTEMPORARY LANES ALSO SIDE-BY-SIDE WITH GENERAL PURPOSE LANES
## PRICING OF HOV’S

<table>
<thead>
<tr>
<th>HOV-2+ free at all times</th>
<th>HOV-2+ free peak only</th>
<th>HOV-3+ free with limits</th>
<th>HOV-3+ discount</th>
<th>No HOV benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-15 (CA)</td>
<td>I-10 (TX)</td>
<td>I-95 (FL)</td>
<td>SR-91*</td>
<td>Loop 375</td>
</tr>
<tr>
<td>I-25</td>
<td>I-45</td>
<td>I-85</td>
<td>I-635</td>
<td>Loop 1</td>
</tr>
<tr>
<td>SR 167</td>
<td></td>
<td>I-495</td>
<td>I-35E (TX)</td>
<td>I-595</td>
</tr>
<tr>
<td>I-35W</td>
<td></td>
<td>SR-91*</td>
<td></td>
<td>I-95 (MD)</td>
</tr>
<tr>
<td>I-394</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-680</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SR-237 / I-880</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-15 (UT)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

I-635, Dallas
FREQUENCY OF USE

Most customers are infrequent users
- Industry average = 3 trips per month

Very frequent users are often immune from being managed
- Price insensitive users
- Free users

LOOP1 EXPRESS (AUSTIN)

- 71% use the service 1 day
- 13% use the service 2 days
- 5% use the service 3 days
- 3% use the service 4 days
- 2% use the service 5 days

- 64% use the service 1 day
- 14% use the service 2 days
- 6% use the service 3 days
- 4% use the service 4 days
- 3% use the service 5 days
REVENUE EXPECTATIONS

Priced Express Lanes Revenue (2011 - 2016)

- Median Revenue (Single Lane): $1.95 M (2016)
- Median Revenue (Dual Lane): $35.8 M (2016)
WHEN THINGS DON’T GO RIGHT
# I-394 Minneapolis

<table>
<thead>
<tr>
<th>Feature</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year Opened</td>
<td>2005</td>
</tr>
<tr>
<td>Length</td>
<td>11 miles</td>
</tr>
<tr>
<td>Directional lanes</td>
<td>1 lane each direction / 2 lane reversible</td>
</tr>
<tr>
<td>Access Type</td>
<td>5 Access Points</td>
</tr>
<tr>
<td>Separation Type</td>
<td>Painted Buffer</td>
</tr>
<tr>
<td>Transit</td>
<td>Moderate Bus Frequency</td>
</tr>
<tr>
<td>Capital Cost</td>
<td>$10M</td>
</tr>
<tr>
<td>Innovations</td>
<td>First use of buffer separation; mobile enforcement; static signage with DMS</td>
</tr>
</tbody>
</table>
I-394 MINNEAPOLIS

What Went Wrong
- Opened with 24 hours operation
- Increase in general purpose lane congestion
  - Observed in off-peak direction
  - Unanticipated outcome
- Increase due to a reduction in GP lane capacity
  - Prior HOV configuration permitted GP traffic in off-peak times / directions
- Legislature began considering a bill to reverse the I-394 Express Lanes
  - Within first three weeks of operation

What Was Changed
- MnDOT changes operations in response to legislature and public
  - Instituted peak hour / peak direction policy
  - 6 am – 10 am inbound
  - 2 pm – 7 pm outbound

Outcome
- Concerns alleviated
  - Continuously operated since 2005
  - Support for new lanes on I-35W and I-35E
- Mitigation depressed revenue
- Created precedent for all facilities
### I-85 ATLANTA

<table>
<thead>
<tr>
<th>Year Opened</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>15.5 miles</td>
</tr>
<tr>
<td>Directional lanes</td>
<td>1 lane each direction</td>
</tr>
<tr>
<td>Access Type</td>
<td>7 Weave Lanes</td>
</tr>
<tr>
<td>Separation Type</td>
<td>Painted Buffer</td>
</tr>
<tr>
<td>Transit</td>
<td>Adjacent to corridor</td>
</tr>
<tr>
<td>Capital Cost</td>
<td>$60M</td>
</tr>
<tr>
<td>Innovations</td>
<td>Registered carpool accounts, Mobile toll app, Mobile enforcement, Virtual barrier system</td>
</tr>
</tbody>
</table>
I-85 ATLANTA

What Went Wrong

- Restored flow to overused HOV lanes
  - Converted congested HOV-2+ lane to priced managed lane with HOV-3+ toll-free with registration
- Substantial increase in general purpose lane congestion
  - By design, removing vehicles from express lanes
- Dynamic pricing algorithm imposed very high toll rates
  - Algorithm overly considered conditions in general purpose lanes when setting tolls

Measureable Impacts

- Vehicular Throughput
  - AM Peak: 6.6% decline
  - PM Peak: 2.9% decline
- Person Throughput
  - AM Peak: 9.9% decline
  - PM Peak: 6.3% decline
- Vehicle Occupancy
  - HOV-2: 30% (AM) decline
  - AVO: 2.0 → 1.2 person/vehicle

Source: Georgia Tech, College of Engineering
http://transportation.ce.gatech.edu/hov2hot
I-85 ATLANTA

What Was Changed

→ Governor Deal intervened in the first five days to implement changes
  ▪ Placed cap on tolls
  ▪ Required across-the-board reduction in toll rate
  ▪ Opened additional access points to / from facility with restriping
→ Implemented a “human factor” in toll rate setting
  ▪ Replaced algorithm with human setting of toll rates
  ▪ Algorithm “shadowed” changes and helped inform human operators
→ Changed algorithm
  ▪ No longer over-represented GP congestion in calculations

Outcomes

→ Public, legislative, and media concerns alleviated
  ▪ Changes were institutionalized
  ▪ Express Lanes operate at / near maximum flow rates
→ Expansion of express lanes concept (under same Governor)
  ▪ Extension of I-85 Express Lanes
  ▪ I-75 / I-575 (Northwest) under construction
  ▪ I-75 (South) also under construction
  ▪ Managed lanes key component of Governor’s 10 year strategic plan
<table>
<thead>
<tr>
<th><strong>I-110 LOS ANGELES</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Year Opened</strong></td>
</tr>
<tr>
<td><strong>Length</strong></td>
</tr>
<tr>
<td><strong>Directional lanes</strong></td>
</tr>
<tr>
<td><strong>Access Type</strong></td>
</tr>
<tr>
<td><strong>Separation Type</strong></td>
</tr>
<tr>
<td><strong>Transit</strong></td>
</tr>
<tr>
<td><strong>Capital Cost</strong></td>
</tr>
<tr>
<td><strong>Innovations</strong></td>
</tr>
</tbody>
</table>
I-110 LOS ANGELES

What Went Wrong

→ Northern end congestion
  ▪ Terminus in downtown Los Angeles involves critical bottleneck
  ▪ Although lane split, demand does not follow split
  ▪ Backups occur in both express lanes and general purpose lanes

→ Congestion at access points
  ▪ HOV only facilities on I-105 feed into I-110 Managed Lanes
  ▪ High weaving volumes at junctions

What Went Wrong

→ HOV violations increased substantially
  ▪ Change to switchable transponders yielded more willful violators
  ▪ 24 – 29% estimated violation rates in 2013 / 2014 operations
I-110 LOS ANGELES

What Was Changed

→ Reduce demand at bottlenecks
  - $16M revenue reinvested for resolving traffic at bottlenecks
  - Changes in dynamic pricing algorithm to adjust to growing traffic volumes

→ Increased enforcement to reduce “unmetered” violators
  - Violation rates declined to 10 – 12% when CHP actively patrolling
  - Exploring additional changes
    - Application of automated vehicle occupancy enforcement to aid CHP
    - HOV-2+ to HOV-3+ change

Outcomes

→ Public support for continuing Express Lanes
  - Built-in sunset into project
  - Extensive public outreach / hearings yielded 58% support; 25% oppose

→ Legislative removal of sunset date
  - Both I-110 and I-10 Express Lanes
  - Indefinite continuation (2015)

→ L.A. County Metro is developing additional Express Lanes
  - I-110 Extension (pre-design)
  - I-105 (pre-design)
  - I-405 (pre-design)
## I-15 SALT LAKE CITY

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year Opened</td>
<td>2010</td>
</tr>
<tr>
<td>Length</td>
<td>40 miles</td>
</tr>
<tr>
<td>Directional lanes</td>
<td>1 each direction</td>
</tr>
<tr>
<td>Access Type</td>
<td>Near Continuous</td>
</tr>
<tr>
<td>Separation Type</td>
<td>Skip / Painted Buffer</td>
</tr>
<tr>
<td>Transit</td>
<td>None</td>
</tr>
<tr>
<td>Capital Cost</td>
<td>Appx. $150M</td>
</tr>
</tbody>
</table>
I-15 SALT LAKE CITY

What Went Wrong

→ Facility divided into 4 pricing segments
  ▪ Reduces ability to target benefit of pricing changes

→ Toll rate ceiling of $1.00 per segment
  ▪ Causes significant reduction in speeds in express lanes during peak hours

Impacts
LESSONS AND TRENDS
LESSONS AND TRENDS

→ Freeway Tolling is an increasingly mainstream mobility option
  ▪ Adopted express lanes policies in multiple states
    – Mandate preference for express lanes as new capacity
    – Shift to express lane networks
  ▪ Limited general purpose lane widening in urban areas
  ▪ Preservation of options

→ Still recognize that express lanes are a fundamental change in how we use highway capacity
  ▪ Evolution from “build and forget” to “every day operation”
LESSONS AND TRENDS

➔ Big Projects Require Big Revenue
  ▪ $1B+ reconstruction projects increasingly funded with revenue from express lanes
  ▪ Leverages multiple funding sources
  ▪ Alternative delivery / concession agreements
  ▪ Provides O&M and limited capital coverage

➔ Tolling for revenue involves different fundamental decisions than tolling for traffic management
  ▪ Mechanisms still the same
LESSONS AND TRENDS

➔ Success driven by planning and policy
  ▪ Invest early in education and outreach

➔ Technical, institutional, public acceptance issues can be overcome
  ▪ Don’t oversell the project
  ▪ Create “win” scenarios
  ▪ Listen to constituents
  ▪ Adapt policies to public desires

➔ Establish performance measures and key policies early
  ▪ Agreement on what will constitute success or failure
Express Lanes
A National Perspective on Practice, Experiences, and Outcomes

David H. Ungemah
WSP | Parsons Brinckerhoff
National Managed Lanes Director

15 December 2016