Modeling Express Lanes Using Dynamic Traffic Assignment Models

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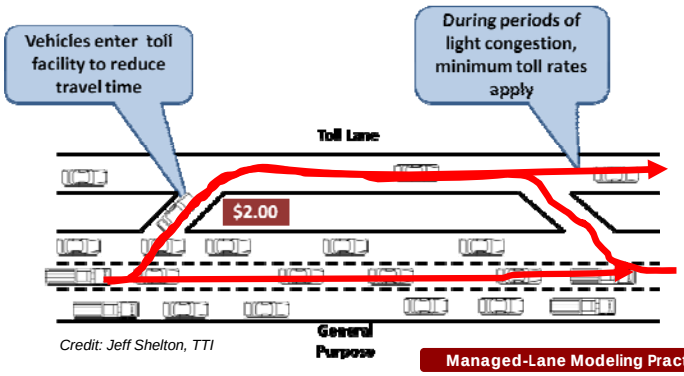
DTA Assumptions

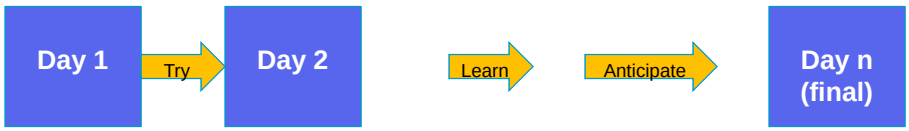
- By using DTA, you accept the following assumptions
  - Estimating lane demand is a **route/departure** choice, not a mode choice problem.



Credit: Jeff Shelton, TTI

DTA Assumptions

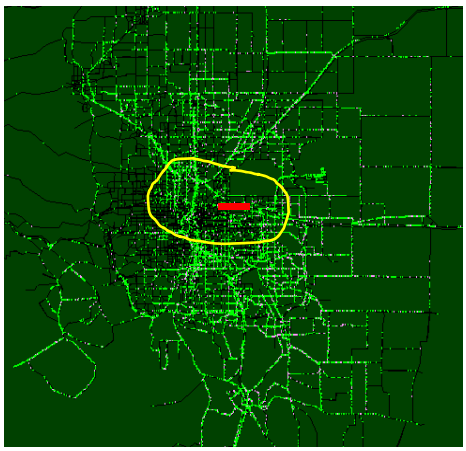
- By using DTA, you accept the following assumptions
  - **Learning** and **adaptation** is part of route choice decisions (in lieu of instantaneous or reactive route choice behavior).



DTA Components for Pricing Analysis

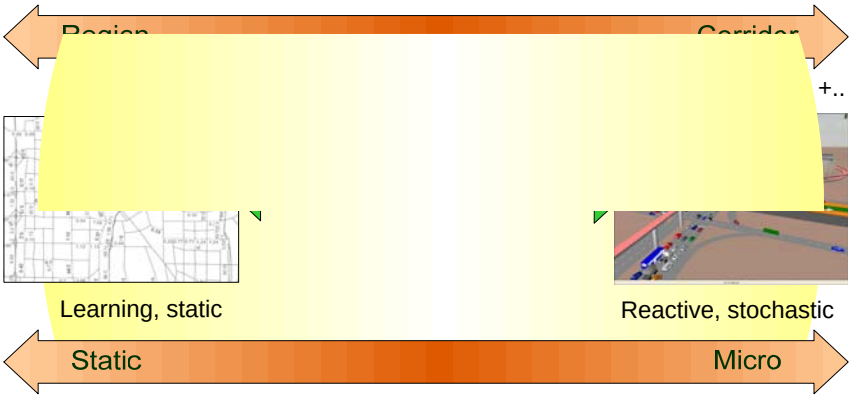
- Pricing model (optional, depending on pricing scheme)
- Route/lane choice model
- Departure time choice model
  - Developed separately
  - Loop back to demand model
- Network needs to large enough to include most trips through the facility. A small area over-penalizes tolled facility.

Sub-Area Scope Implication



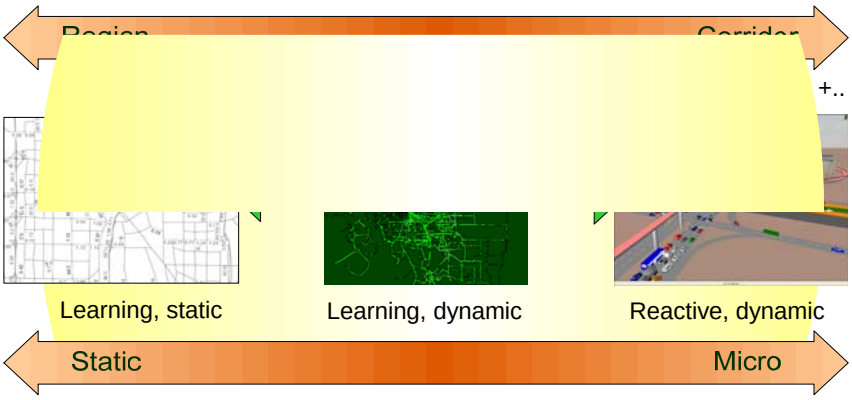
Why DTA for Express Lane Analysis Given We have had Macro-Micro

- Macro-Micro inconsistency
  - Traffic dynamic, route choice behavior



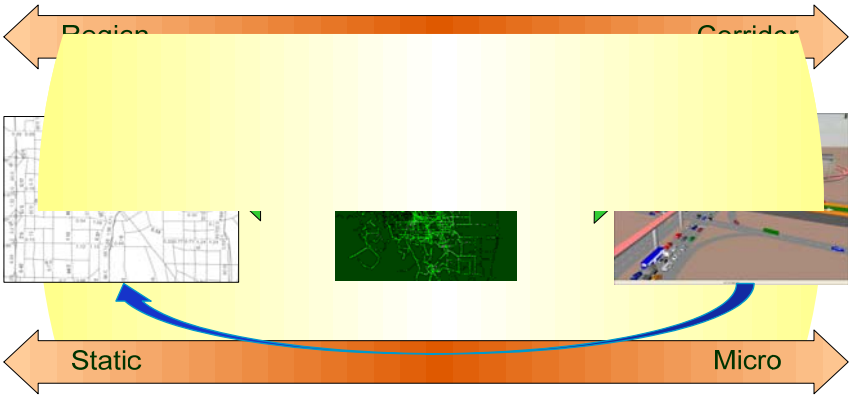
Why DTA for Express Lane Analysis Given We have had Macro-Micro

- Better consistency with Macro-Meso-Micro integration



Why DTA for Express Lane Analysis Given We have had Macro-Micro

- Critical Bridge from Macro to Micro and feedback



Pricing Schemes in Real World

- Samples of a wide range of configurations

	Facility	HOV	SOV/Two-Axial	Commercial/3 + Axial
DUE	HOV Lanes	✓ (Free)	⊘ (Very High)	⊘ (Very High)
DUE	Toll Roads - Fixed rate - ToD rate	✓ (Free/Normal/ Low)	✓ (Normal)	✓ (High)
DUE/ Non-Eq	Managed Lanes - Fixed rate - ToD rate - Congestion Responsive	✓ (Free)	✓ (Varying)	? (Varying, higher)

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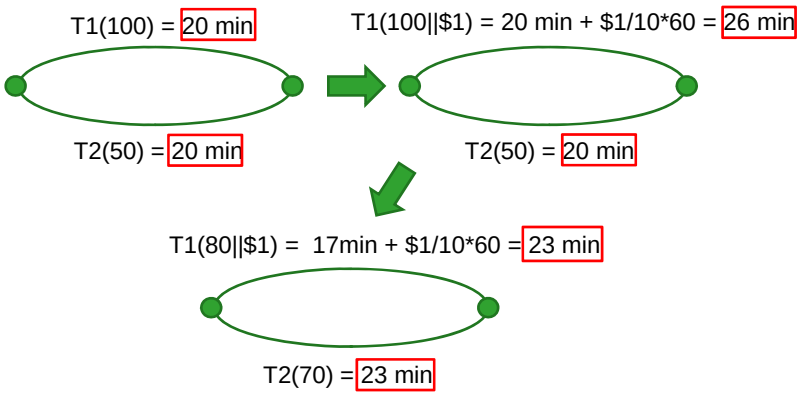
Analyzing Tolling in a Simple Static Case



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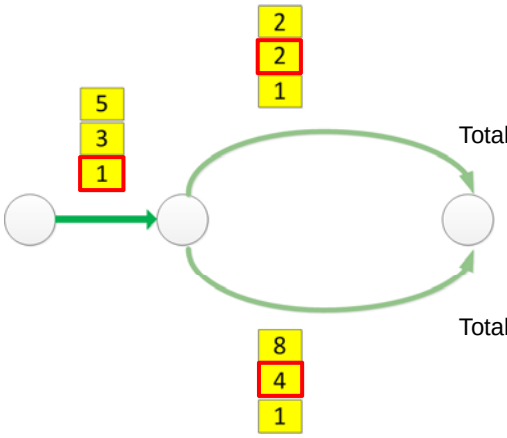
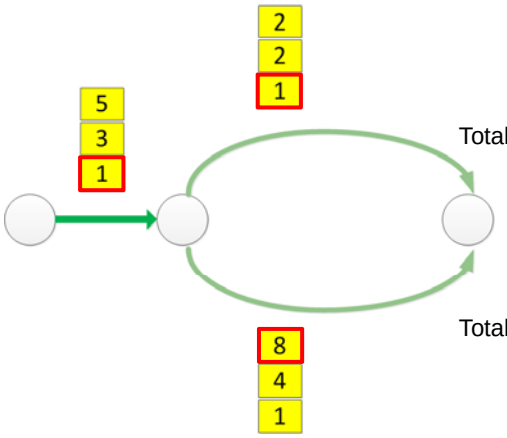
Dynamic Case Fundamental



Total Experienced Time = 3 min

Total Experienced Time = 5 min

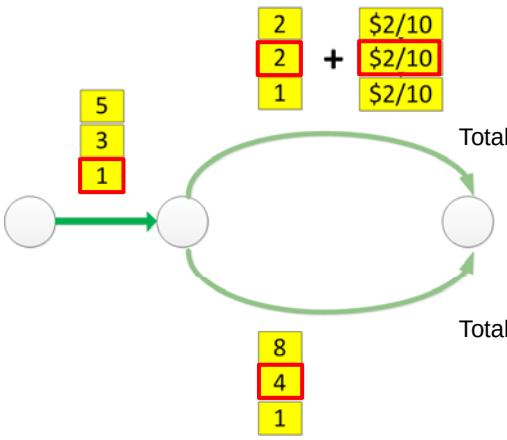
Static/Instantaneous View of the Same Situation



Total Instantaneous Time = 2 min

Total Instantaneous Time = 9 min

Dynamic Case With Static Toll



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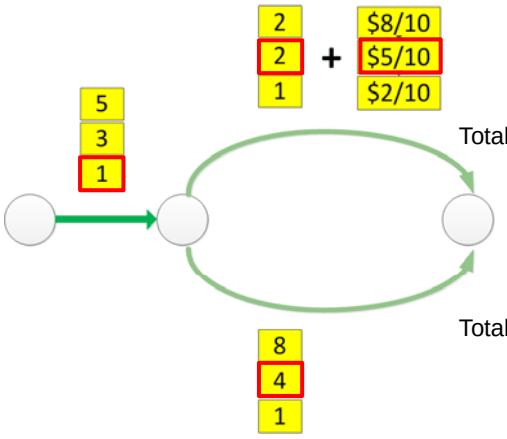
Dynamic Case With Dynamic Toll



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Revenue/Throughput Maximizing Pricing Model

- Pricing Model (vary by software)

+ $8/10
+ $5/10
+ $2/10

$$\max Z = \sum_{l \in L} \sum_{t \in T} k_l^t v(k_l^t)$$

Subject to,

$$v(k_l^t) \geq v_l^0, \qquad \forall\, l \in L, t \in T$$

$$\frac{d_l}{\theta_n}\left(\frac{1}{\bar{v}_l^t} - \frac{1}{v(k_l^t)}\right) \leq \pi, \qquad \forall\, l \in L, t \in T$$

$$\frac{d_l}{\theta_n}\left(\frac{1}{\bar{v}_l^t} - \frac{1}{v(k_l^t)}\right) \geq \pi - \varepsilon, \qquad \forall\, l \in L, t \in T$$

Other DUE Conditions

Where,

k_l^t	: density of CP segment l at time t
$v_l^t(k)$	: speed of CP segment l at time t
v_l^0	: required minimal operating speed inside HOT lane
$\bar{v}_l^t$	: average speed on the GP lane
d_l	: distance of the CP segment l
π_l^t	: toll rate for CP segment l at time t; this is the decision variable.
θ_n	: value of time for vehicle type n
ε	: threshold

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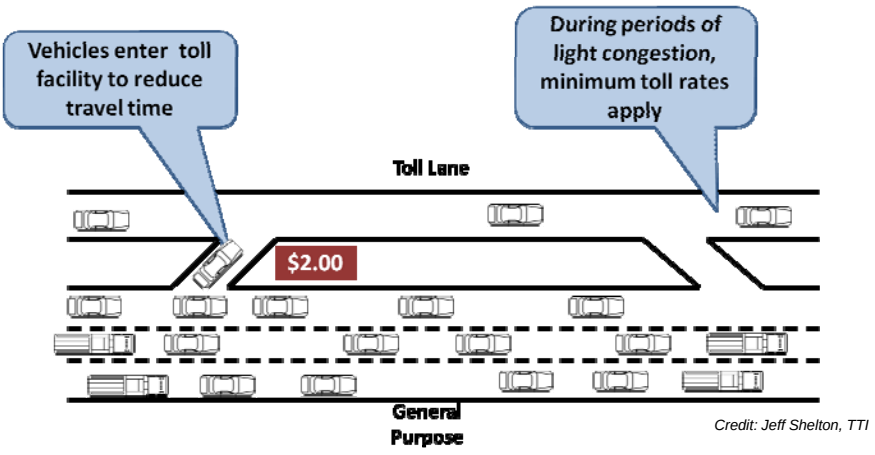
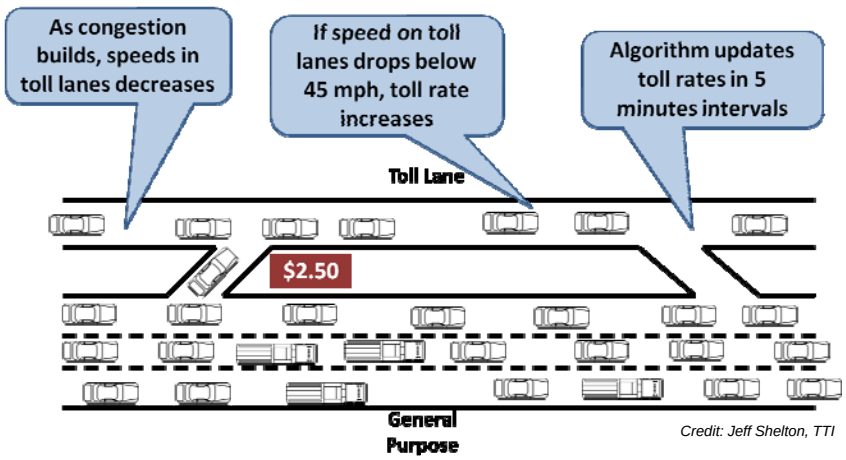
Congestion Responsive Tolling



Credit: Jeff Shelton, TTI

Congestion Responsive Tolling



Maximize throughput while maintaining target speed

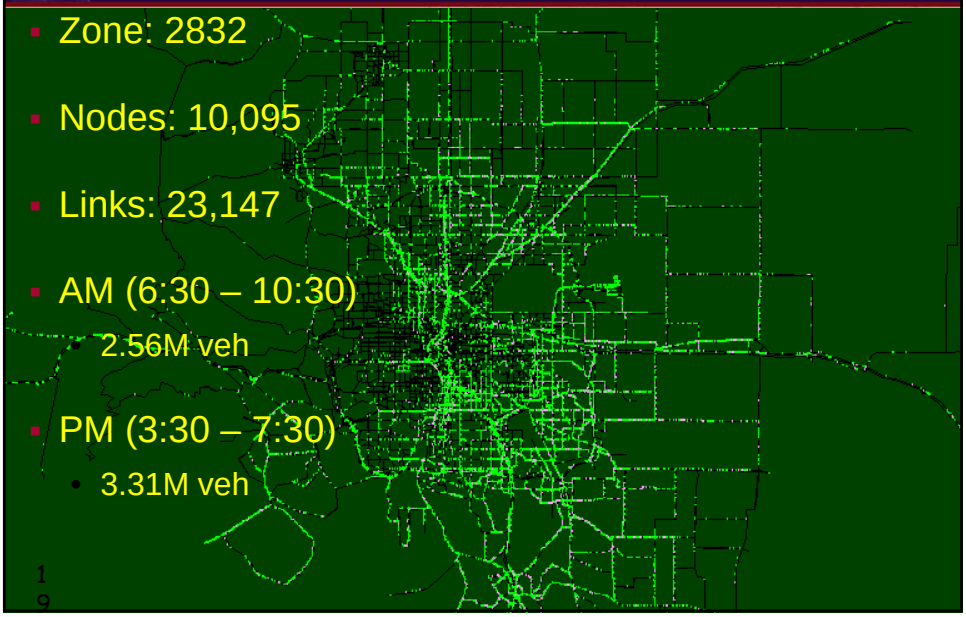
Denver-Boulder US36 Congestion Pricing

- TIGER Applications
- Modeled 3 buildout strategies
- Estimated
  - Congestion
  - Revenue
  - Travel time
  - Fuel consumption
  - Emission

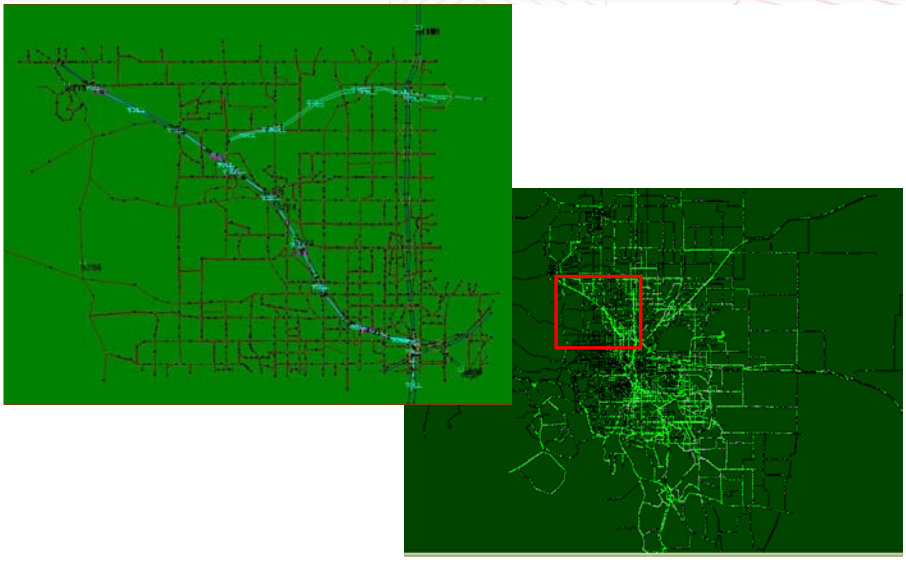
Managed-L

DRCOG Regional Model in DTA

- Zone: 2832
- Nodes: 10,095
- Links: 23,147
- AM (6:30 – 10:30)
  - 2.56M veh
- PM (3:30 – 7:30)
  - 3.31M veh



US 36. Managed Lane Sub-Area



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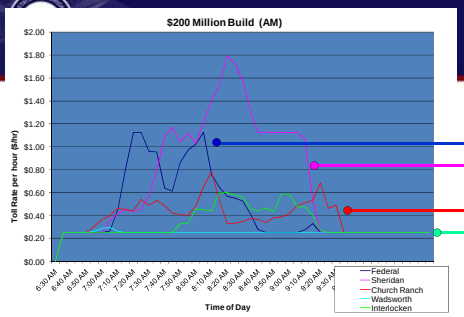
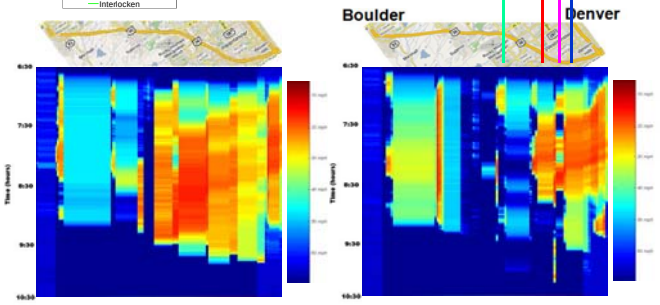
GP Lane Congestion vs. ML





No Build $260 Million Build

Addressing Heterogeneity

- Value-of-Time (VoT) plays a critical role in generalized cost type of DTA approach.
- VoT differs by trip purpose/socio-economic/ location attributes.
- Increasing interesting in DTA and Activity-Based Model (ABM) integration
  - ABM produces trip/person specific VoT.

Addressing Heterogeneity

- Existing approaches

Discrete Choice Model	Multi-Class/Stratified Assignment
- Individual route choice - Utility functions for toll and non-tolled routes	- Stratify population by VoT distribution - Multi-class assignment for each VoT strata
Pros - **Flexible, easy to implement** - **Computational efficient**	**Pros** - **Seek to converge** - **Stable results for scenario comparison**
Cons - Hard to converge - Implication/interpretation	Cons - Computational demanding and becomes intractable with increasing problem size

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Summaries - Toll modeling with DTA

- Include alternate routes to model diversion
  - ✓ Static models do this well.
  - × Microsim not suitable for equilibrium DTA.
    - × Network too small.
    - × Not solving time-dependent shortest path.
  - ✓ DTA networks need to be large enough.
- Local congestion can affect tolls from far away
  - × Static models do not do queues and spillback.
  - ✓ Microsim has lots of detail.
  - ✓ DTA combines sufficient realism with larger-area networks.

Summary

- Advantage of applying DTA for pricing analysis appears to be obvious (hopefully).
- Various approaches are being offered for the following pricing schemes
  - Fixed toll
  - Time-of-day toll
  - Congestion responsive
- Addressing heterogeneity is desired
  - Ongoing research (SHRP2 L04, C10, etc.)
- Importance of feedback