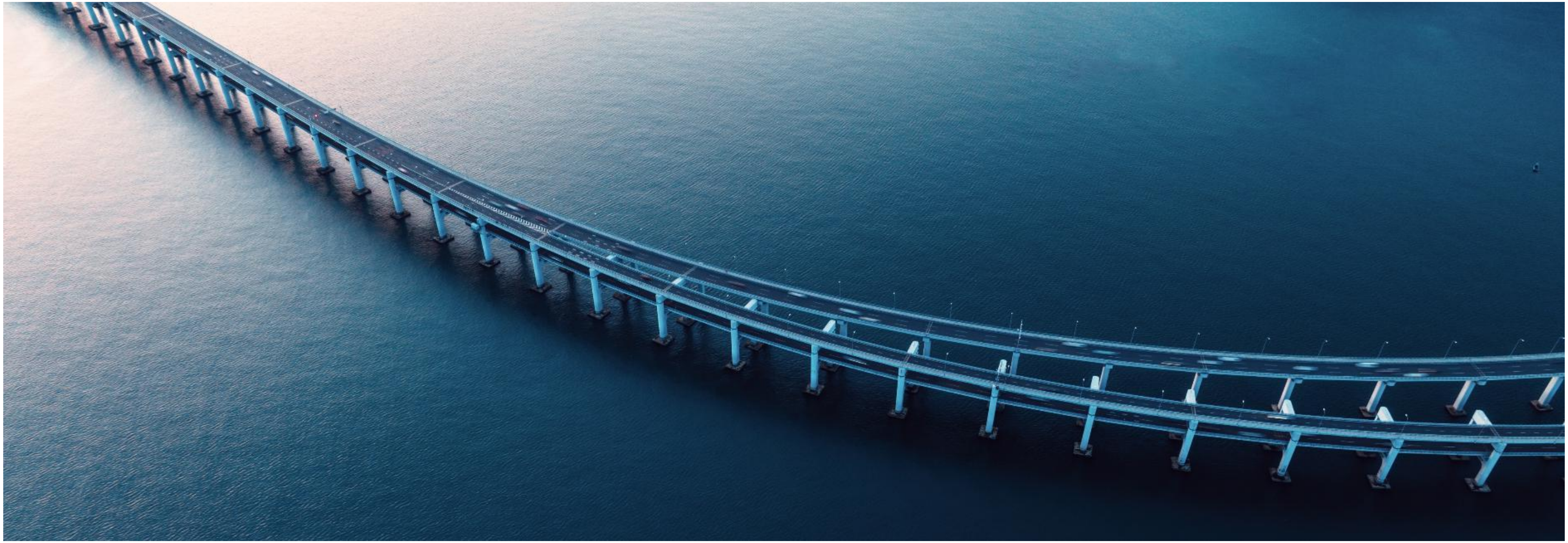
Application of Distributed Value of Time in Agent-Based Dynamic Traffic Assignment (AgDTA) for Toll Road Forecasting

Modeling Mobility 2025

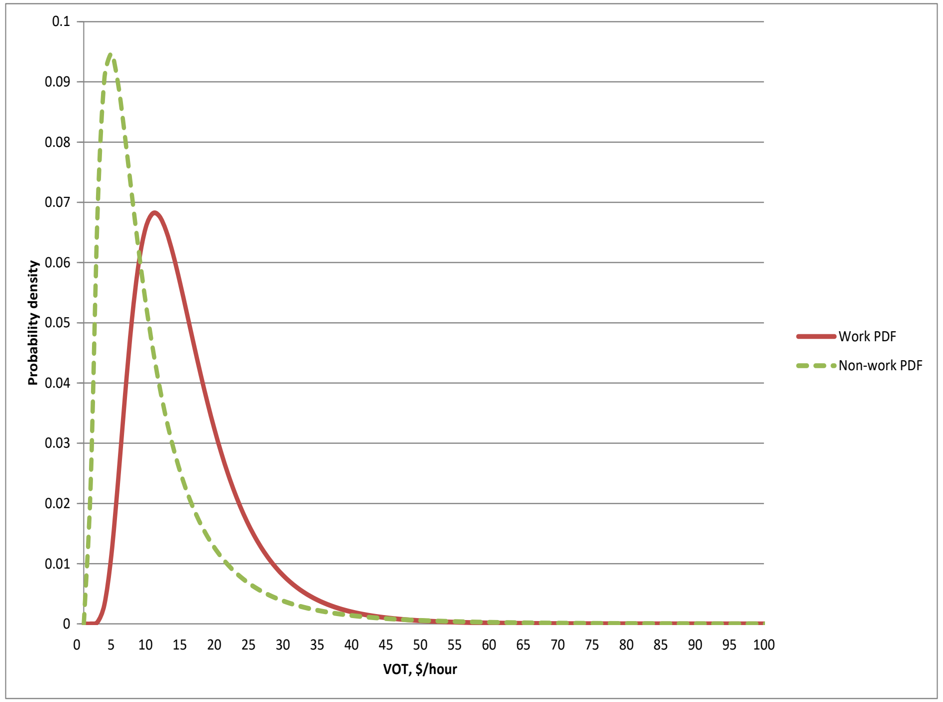


Jim Hicks, Peter Vovsha, Michael Mahut, Ido Juran – Bentley Systems
Haidong Zhu, Arup Dutta – Maricopa Association of Governments

Prior Research on VOT

- Systematic VOT effects
  - Non-linear effects and distance effects (“cost damping”)
  - Perceived travel time by congestion levels and facility type
  - Impact of purpose and perceived urgency of trip
  - Impact of income
  - Impact of car occupancy (“cost sharing”)
  - Impact of gender, age, and other person characteristics
  - Incorporation of reliability measures
  - Toll-averse bias

- Situational variability & unobserved heterogeneity
  - Distributed VOT
  - lognormal, established in prior research



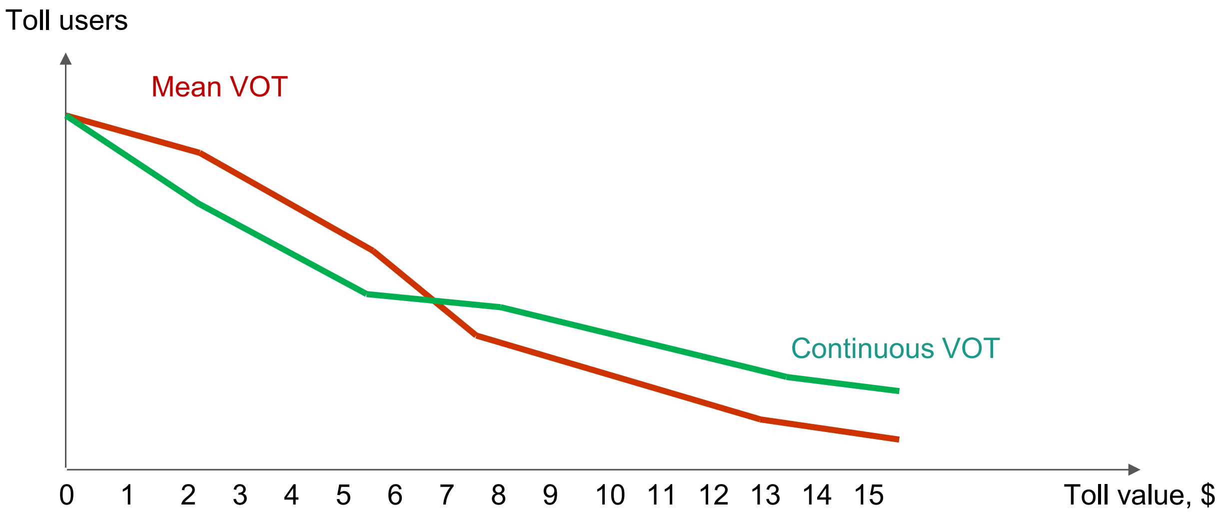
Parameter	Work	Non-work
Mu	2.58	1.98
Sigma	0.50	0.80
Mean	**15.01**	**9.97**
STD	**8.00**	**9.44**

Focus of Analysis

For a given mean VOT, ignoring the distribution tends to result in systematic biases

- For lower tolls:
    - mean VOT will *overestimate* volume of toll users due to *absence of trips* with very low VOT that are *not willing to pay* these tolls (divert)
- For higher tolls:
    - mean VOT will *underestimate* volume of toll users due to *absence of trips* with very high VOT that would be *willing to pay* these tolls (not divert)

- In this study, a series of tests were carried out to study this relationship empirically in the context of a full-scale ABM-DTA model



DTA Components for ABM Integration

Route choice based on trip-specific VOT

- VOT distribution essential for pricing studies
- Consistency between mode choice in ABM and route choice in DTA

Features for ABM-DTA integration and run time

- Concurrent sampling with ABM

Efficient mesoscopic DTA for regional-scale

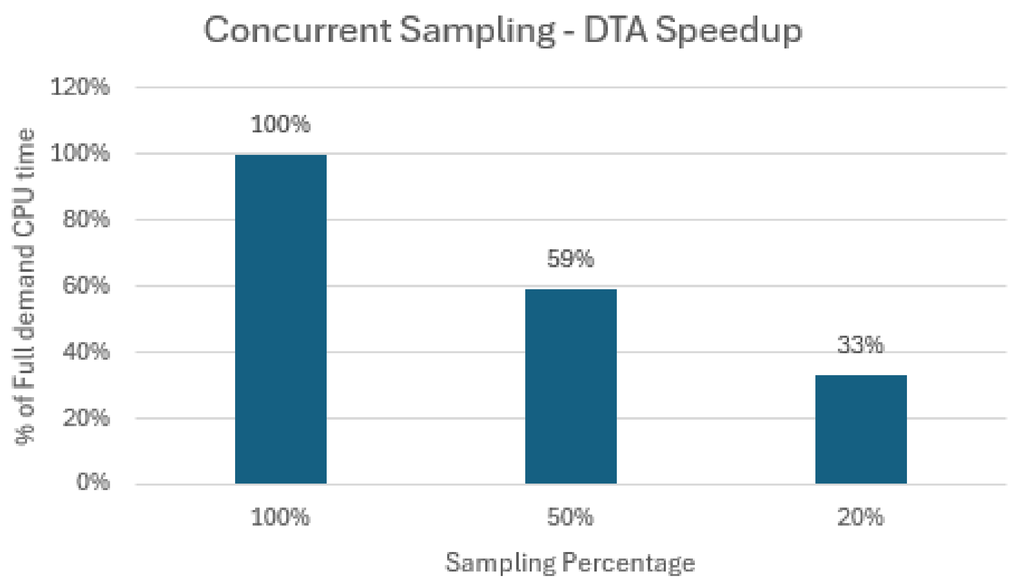
- Very fast run times using multi-threaded event-based simulation
- Gridlock avoidance algorithm ensures model convergence for variable/future demand

DTA Components for ABM Integration

Concurrent Sampling

= Multi-Resolution Mesoscopic Simulation

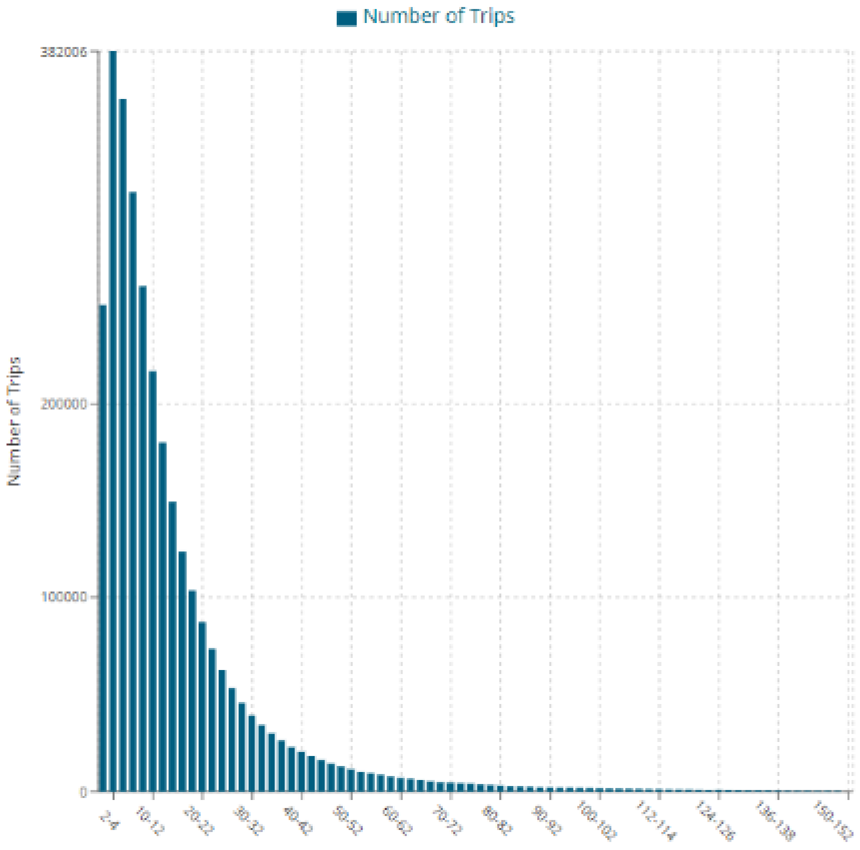
- Simulation parameters are scaled “under the hood” for all simulation components: car following, lane changing, gap acceptance
- Produces link volumes and speeds that approximate outputs obtained with a 100% demand
- Dramatic reduction in DTA run time with modest reduction in fidelity



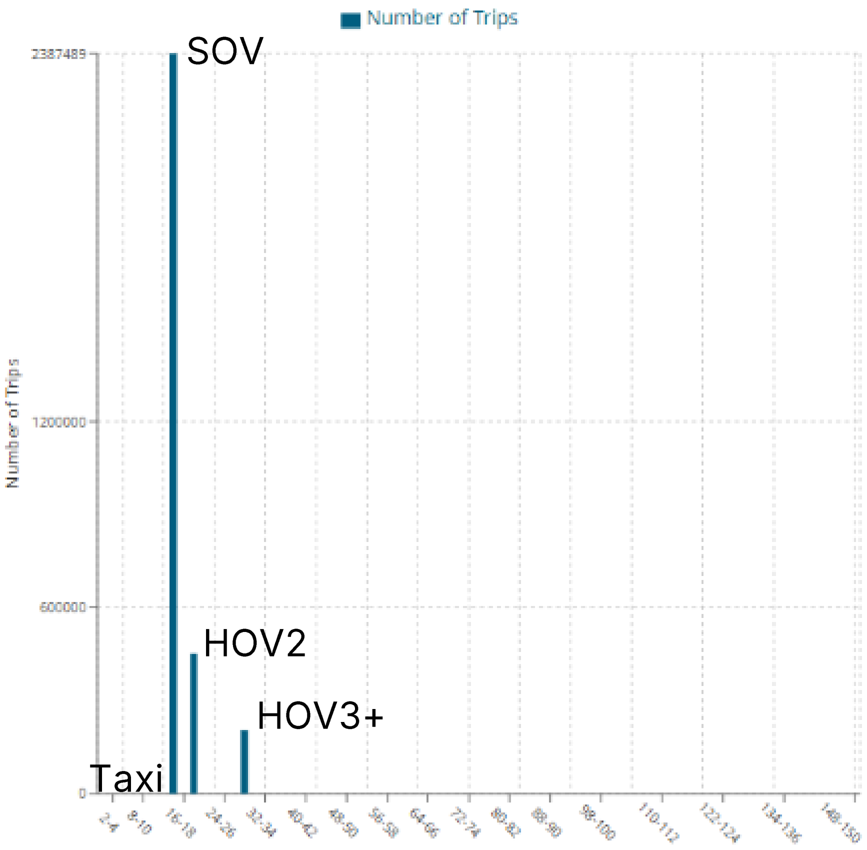
Run times from MAG future year scenario

Distributed vs. Mean VOT

Distributed: 100 bins



Mean: 4 Discrete Values



Practical method used in this study

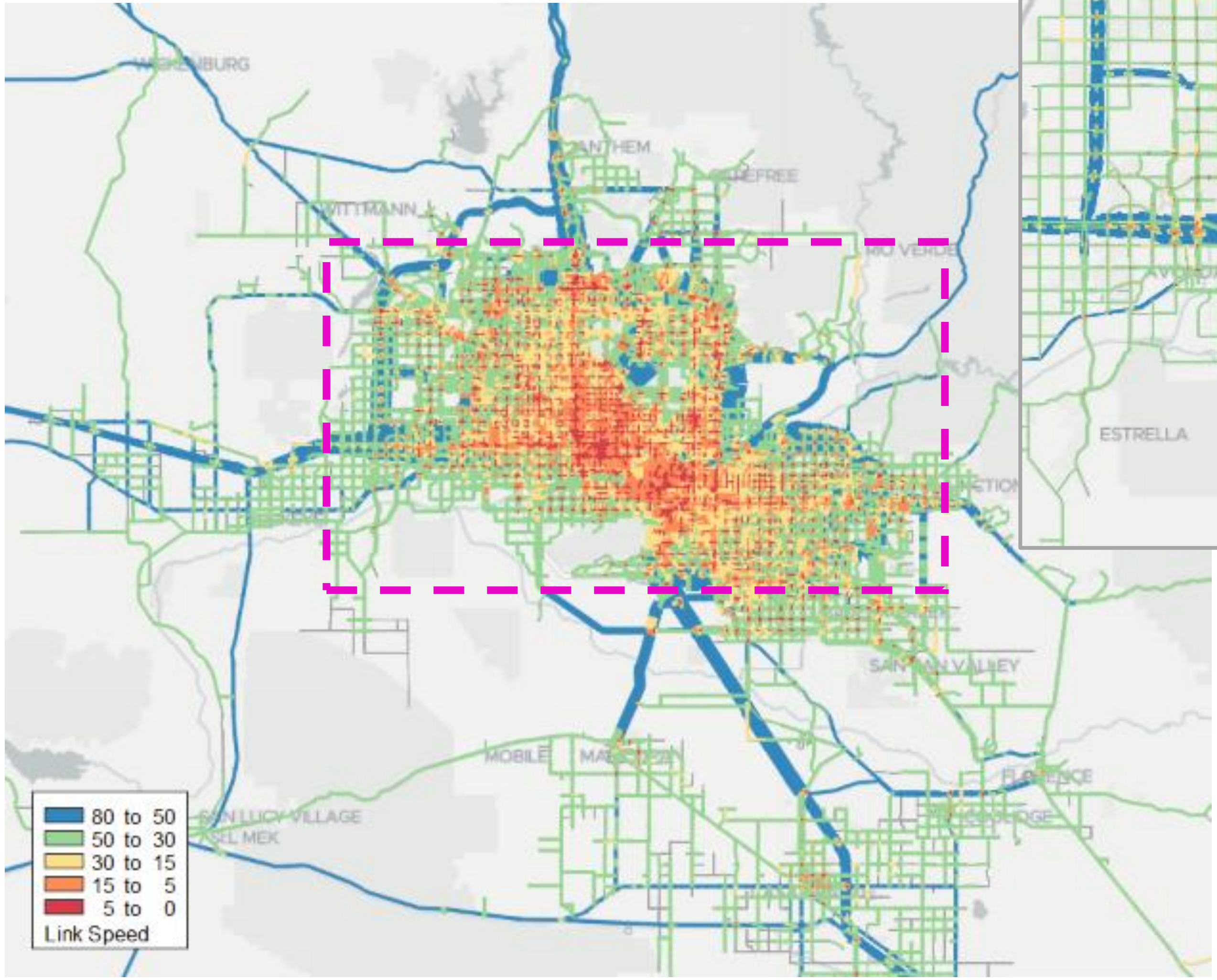
ABM

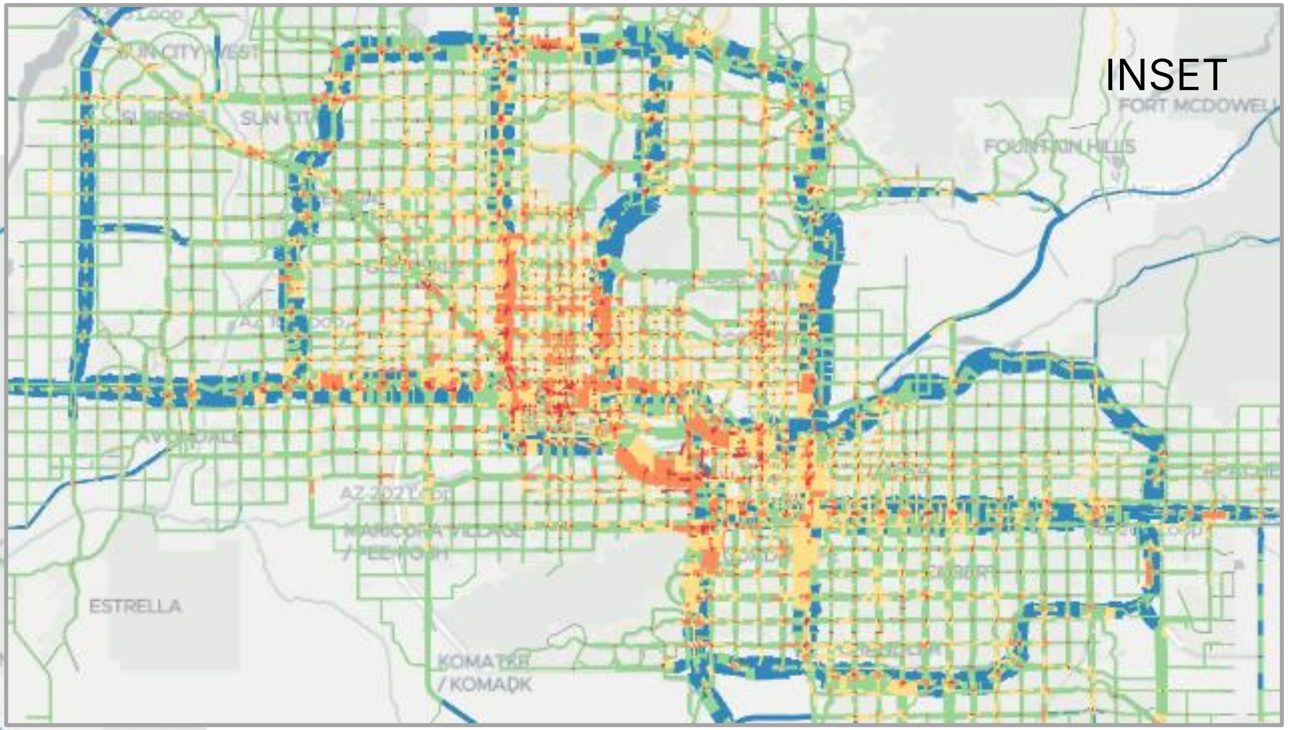
- Calculate segmented VOT by systematic factors (purpose, income, car occupancy)
- Randomize VOT for each vehicle trip to account for situational variability:

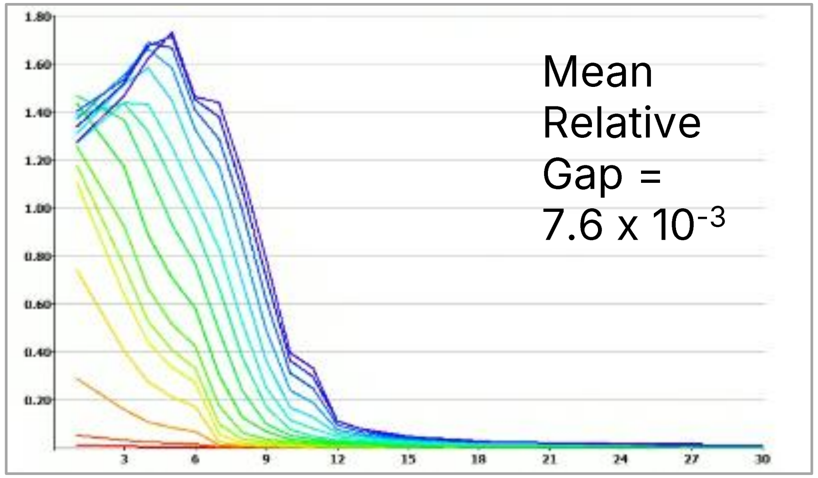
$$\exp(VOT_{dev} * rand_{N(0,1)} + \ln(VOT_{mean}) - VOT_{dev}{}^2/2)$$

DTA

- Aggregate VOT into bins for each vehicle class for runtime performance
- Explore number of bins; more bins approach continuously distributed VOT (AgDTA)


ANTHEM
80 to 50
50 to 30
30 to 15
15 to 5
5 to 0
Link Speed


INSET
SUN CITY WEST
SUN CITY
FOUNTAIN HILLS
ESTRELLA

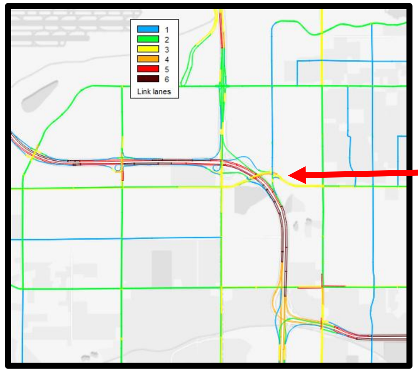

Mean Relative Gap = 7.6×10^{-3}
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
3
6
9
12
15
18
21
24
27
30

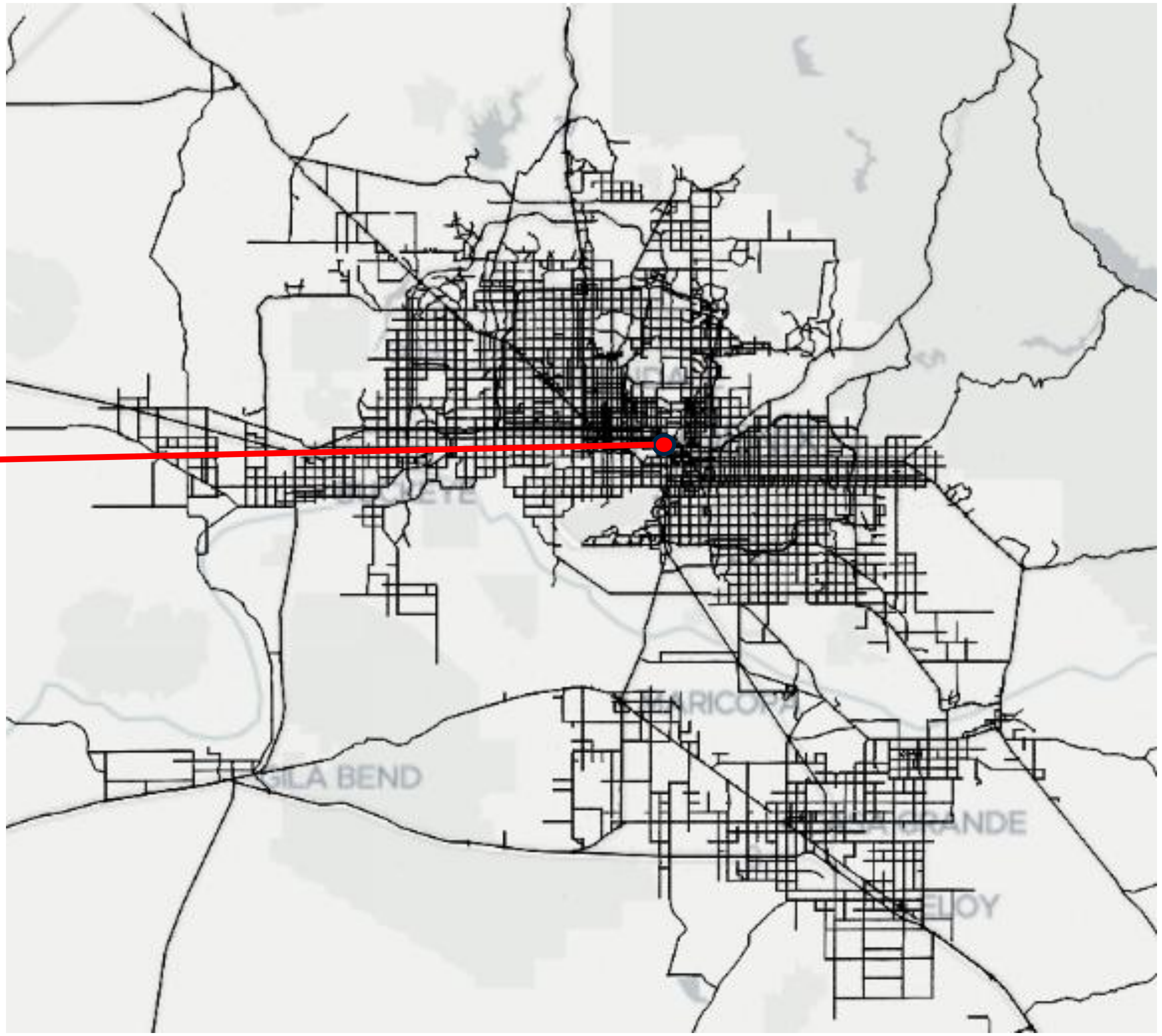
MAG Regional Model (Phoenix, AZ)

Toll tests

Point toll on I-10 Northbound

7 toll levels ($): 0.25, 1, 2, 3, 6, 9, 12





Network

~55K links

3,386 zones

~250 transit lines

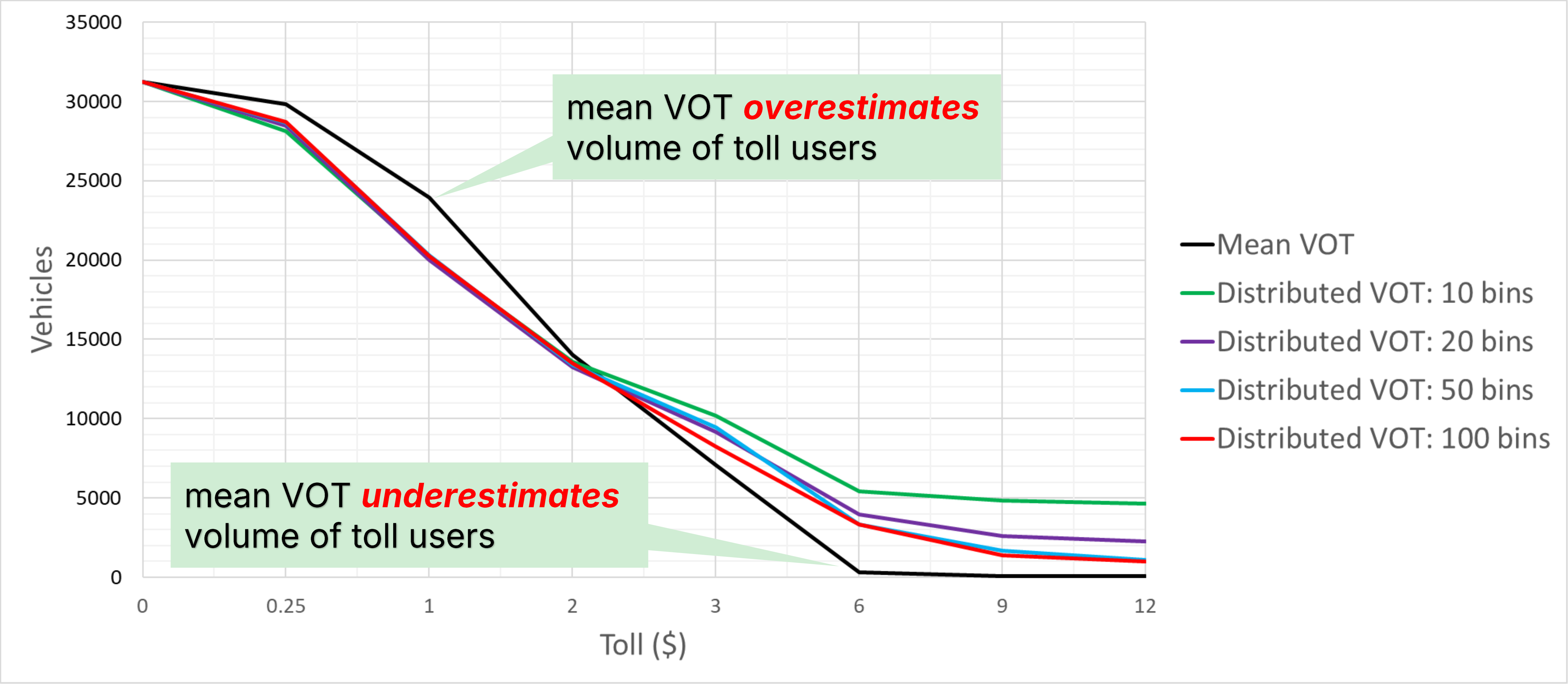
Fixed Demand

4-h demand period (05:30-09:30) for 6-9 AM peak

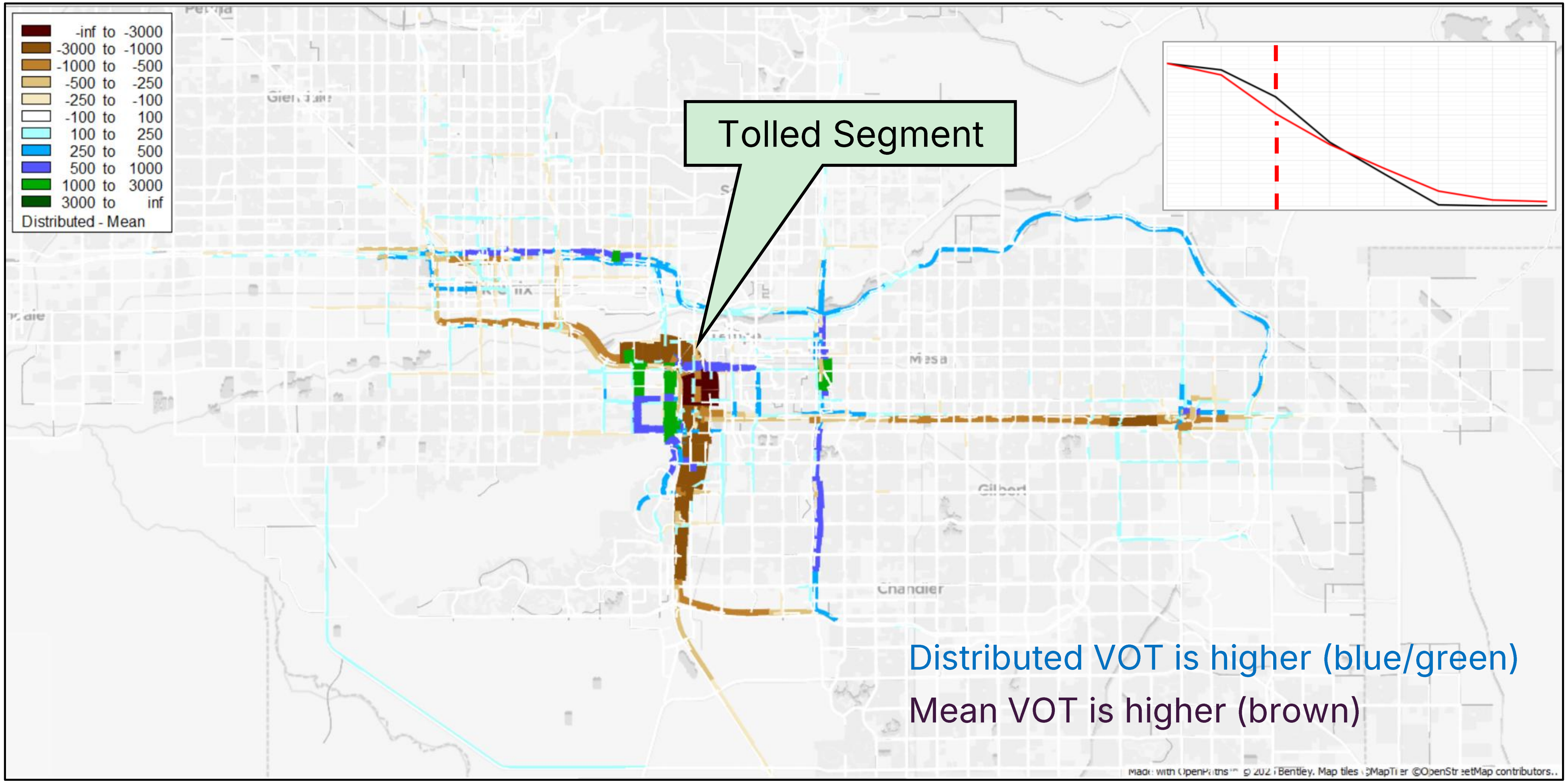
10 vehicle classes + transit

Total trips: ~2.6M

Toll Users vs. Toll Price
Cumulative Demand Through Simulation Period

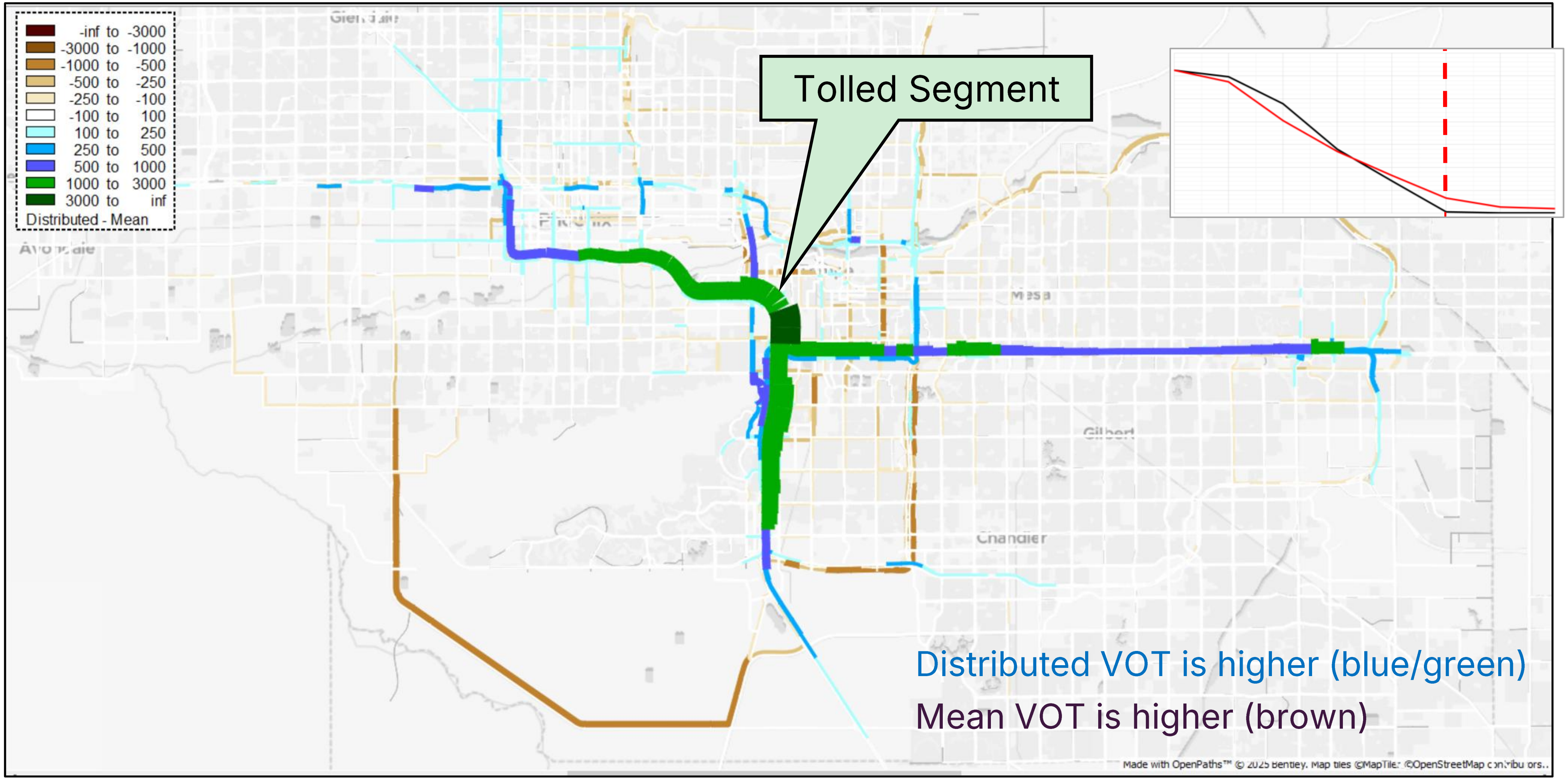


Toll = 1$



-inf to -3000
-3000 to -1000
-1000 to -500
-500 to -250
-250 to -100
-100 to 100
100 to 250
250 to 500
500 to 1000
1000 to 3000
3000 to inf
Distributed - Mean
Tolled Segment
Mesa
Gilbert
Chandler
Distributed VOT is higher (blue/green)
Mean VOT is higher (brown)

Toll = 6$


-inf to -3000
-3000 to -1000
-1000 to -500
-500 to -250
-250 to -100
-100 to 100
100 to 250
250 to 500
500 to 1000
1000 to 3000
3000 to inf
Distributed - Mean
Tolled Segment
Mesa
Gilbert
Chandler
Distributed VOT is higher (blue/green)
Mean VOT is higher (brown)

Conclusions

Numerical results from a full-scale ABM-DTA model confirmed the expected trend for the given VOT distributions and toll costs.

- For lower tolls (~ $1): mean VOT *overestimated* volume of toll users by approximately 20%
- For higher tolls ($6+): mean VOT *underestimated* volume of toll users by approximately 90%

The magnitude of these systematic biases warrants a word of caution for utilizing a simplified representation of VOT in practice.

Note: All model runs were carried out using the MAG ABM and OpenPaths DYNAMEQ early-access release

Thank you

jim.hicks@bentley.com, peter.vovsha@bentley.com, michael.mahut@bentley.com, ido.juran@bentley.com

hzhu@azmag.gov, adutta@azmag.gov