Modeling Autonomous Vehicles

MTMUG Presentation, November 14, 2017

Presentation Outline

1. Characteristics of Autonomous Vehicles
2. Derived Implications and Secondary Impacts
3. Scenarios
4. First Tier Model Applications
5. Second Tier Model Applications
6. Third Tier Model Applications
7. Twin Cities Model Application
8. Examples of Results
9. Additional Research

1. AV Characteristics

— Self-Driving Capabilities
— Vehicle and Environment Sensing
— V2I and V2V Connected
— Rational Route Choice
— Electric Power Source

1.1 Implications of Self Driving Capabilities

- Driverless Trips for vehicle positioning and use
- Access to mobility for Disabled, Youth, Elderly
- Transit Access and Egress via drop-off mode
- Automated freight use
- Maintenance activities
- Cost of deliveries lower

1.2 Implications of Environment sensing

- Improved Safety, reduced crashes
- Decreased headways
- Greater resilience to system breakdown

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1.3 Implications of V2I and V2V Connected

- V2I – optimization of signals
- Sophisticated Wayfinding
- V2V – faster response to traffic flow changes

1.4 Implications of Rational Route Choice

- Potential for system-optimal assignment
- Greater response to alternative route messages
- Better emergency response

1.5 Implications of Electric Power Sources

- Cost of Driving more dependent upon electricity generation rates
- Expanded charging station infrastructure
- Improvement in Battery and Motor technology
- Potential for large reductions in emissions if “clean” power is used

2. Secondary Implications

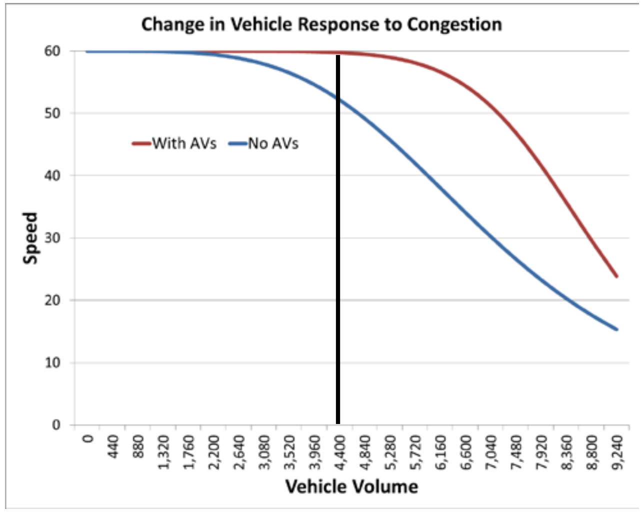
- Parking facility and other land use conversion
- Lower Value of Time – Longer trips
- Daily Activity pattern changes
- Greater Trip generation
- Transit ridership – access or competition
- Transition Management

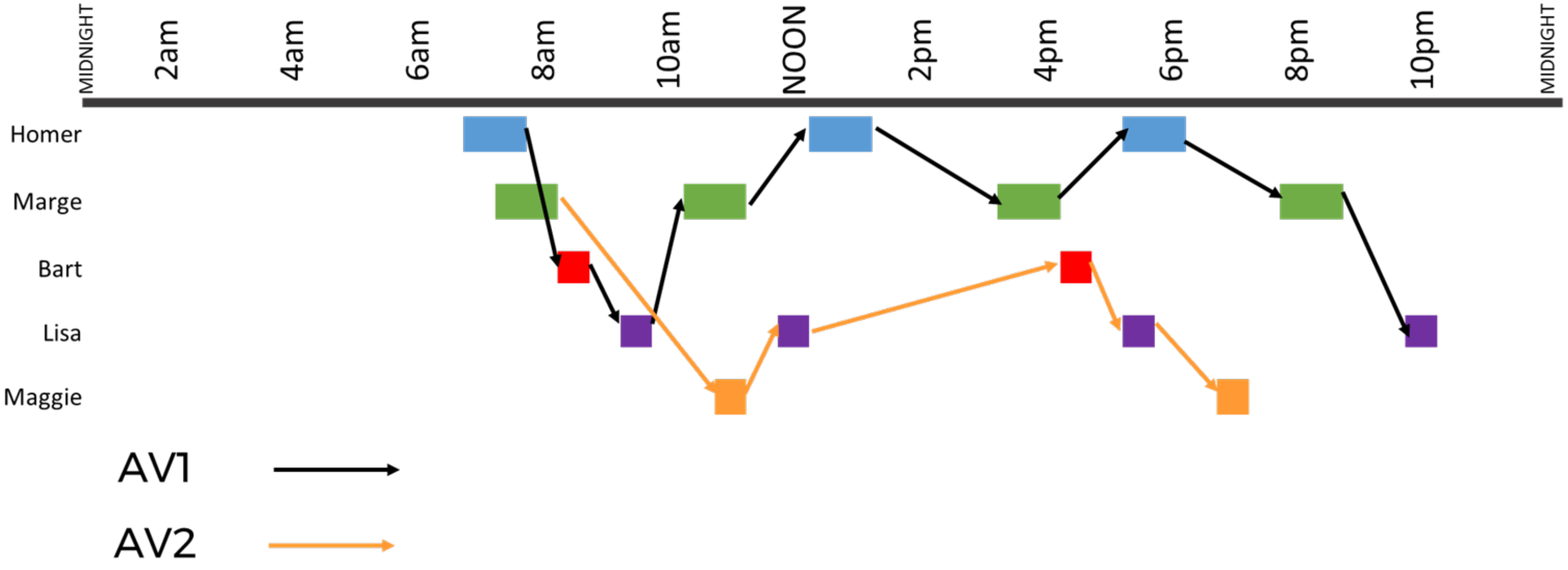
3. Scenarios for AV use

- Ownership Model
- Sharing Model
- Mixed
- Partial Implementation
- Transit Access

4. Model Implications – First Tier

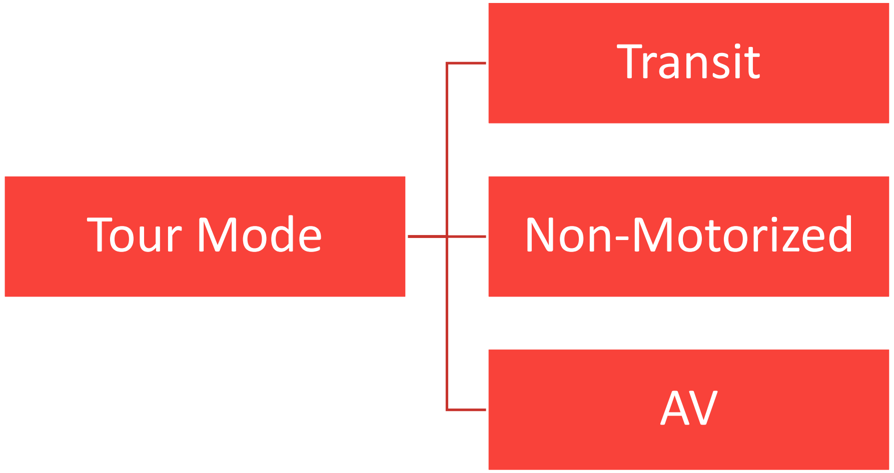
- Auto Accessibility
- Driverless Trips
- Vehicle Performance – headways, VDF





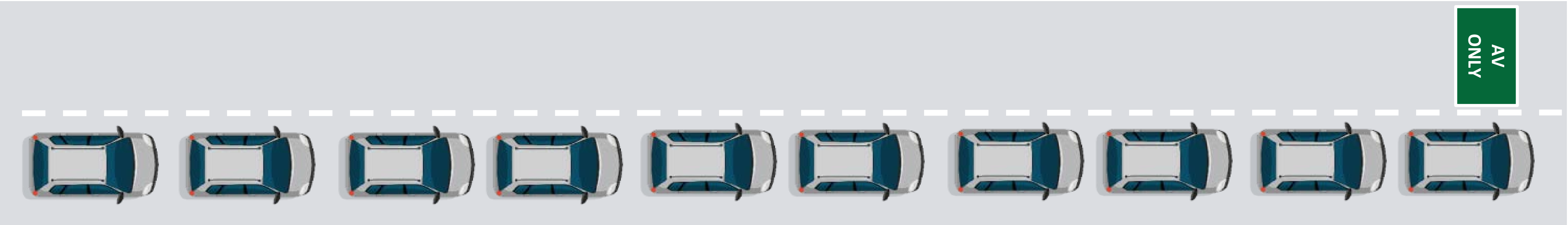
5. Model Implications – Second Tier

- Transit Access and Egress
- Daily Activity Patterns
- Available trip modes within tours
- Treat Shared Ride outside the household as a distinct choice



6. Model Implications – Third Tier

- Dynamic Traffic Assignment –AV driving characteristics
- Land Use changes – Long-term choices, Parking/Recharge Locations



7. Model Application in the Twin Cities

— Cost Assumptions

— Auto Availability

— Capacity Adjustments

— Driverless Vehicle Movements

— Assignment of AVs

— Overall Model Flow, Feedback

Cost Assumptions

- Parking Costs
- Auto Operating Costs
- Value of Time

- Major issue is what is the value of these costs?
- Relatively easy to implement within a model.
- May need to stratify costs between traditional and AVs, Driverless and Occupied.
- Some policy assumptions needed, e.g., tolling

Auto Availability Adjustment for AVs

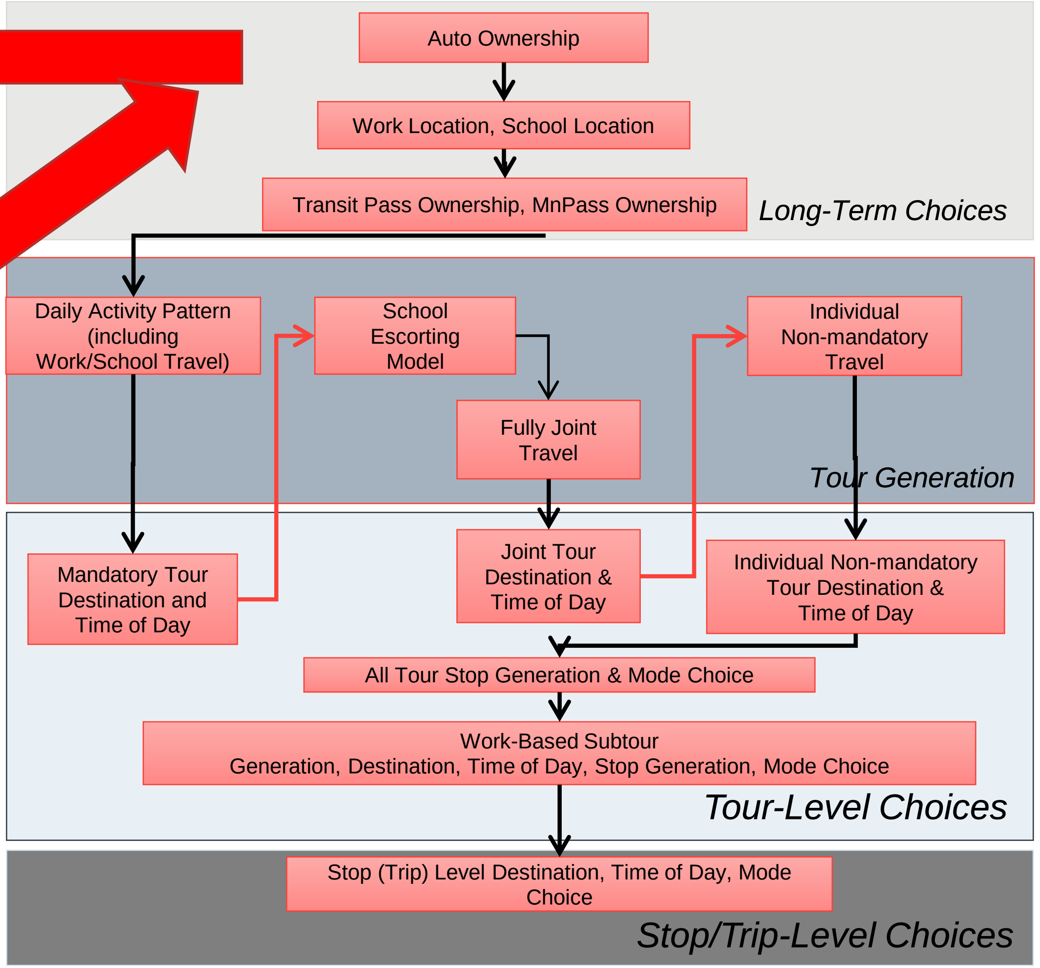
- **AVs will allow access to autos for populations that previously did not have access:**
  - *Elderly and disabled*
  - *Children*
  - *Low income (partially)*
  - *Auto-deficient households*
- **Model Adjustments**
  - *Adjust inputs so that 95% of Households above lowest Income (>25k) have sufficient autos to serve adult population. Adjust to 50% for lowest income group.*

Auto Sufficiency

- A household is auto sufficient if autos>=Adults
- Merge input household file with estimated household autos file and re-compute autos, if necessary, for each household
    1. *If Autos<Adults, then*
        1. If HHINC <=$25k, then set Autos=Adults at a 50% probability
        2. If HHINC >$25k, then set Autos=Adults at a 95% probability
    2. *Else if Autos>=Adults, no change*
- Auto Fleet increased by about 26%

Auto Sufficiency, Placement in Model Stream

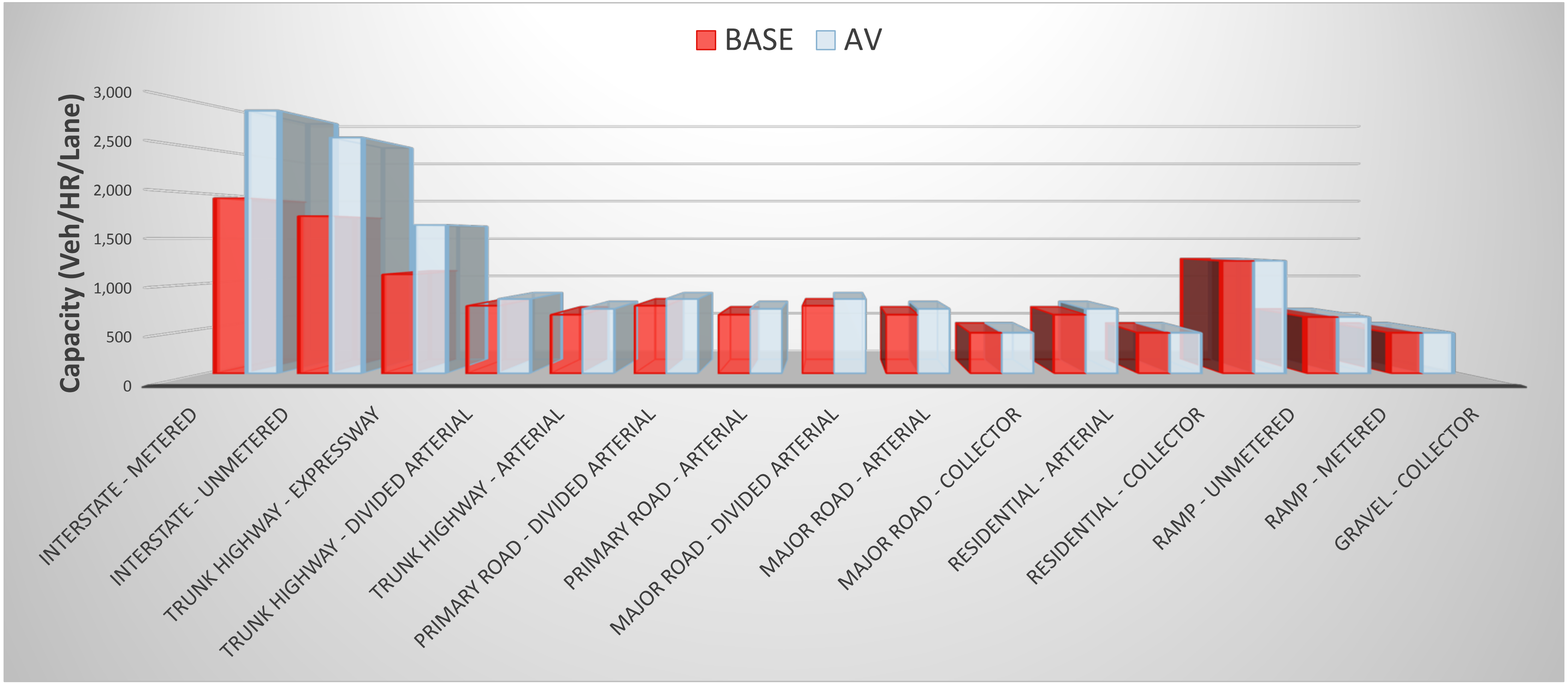
— Auto Sufficiency was adjusted after base model was run through feedback, but prior to tour generation and all other model steps



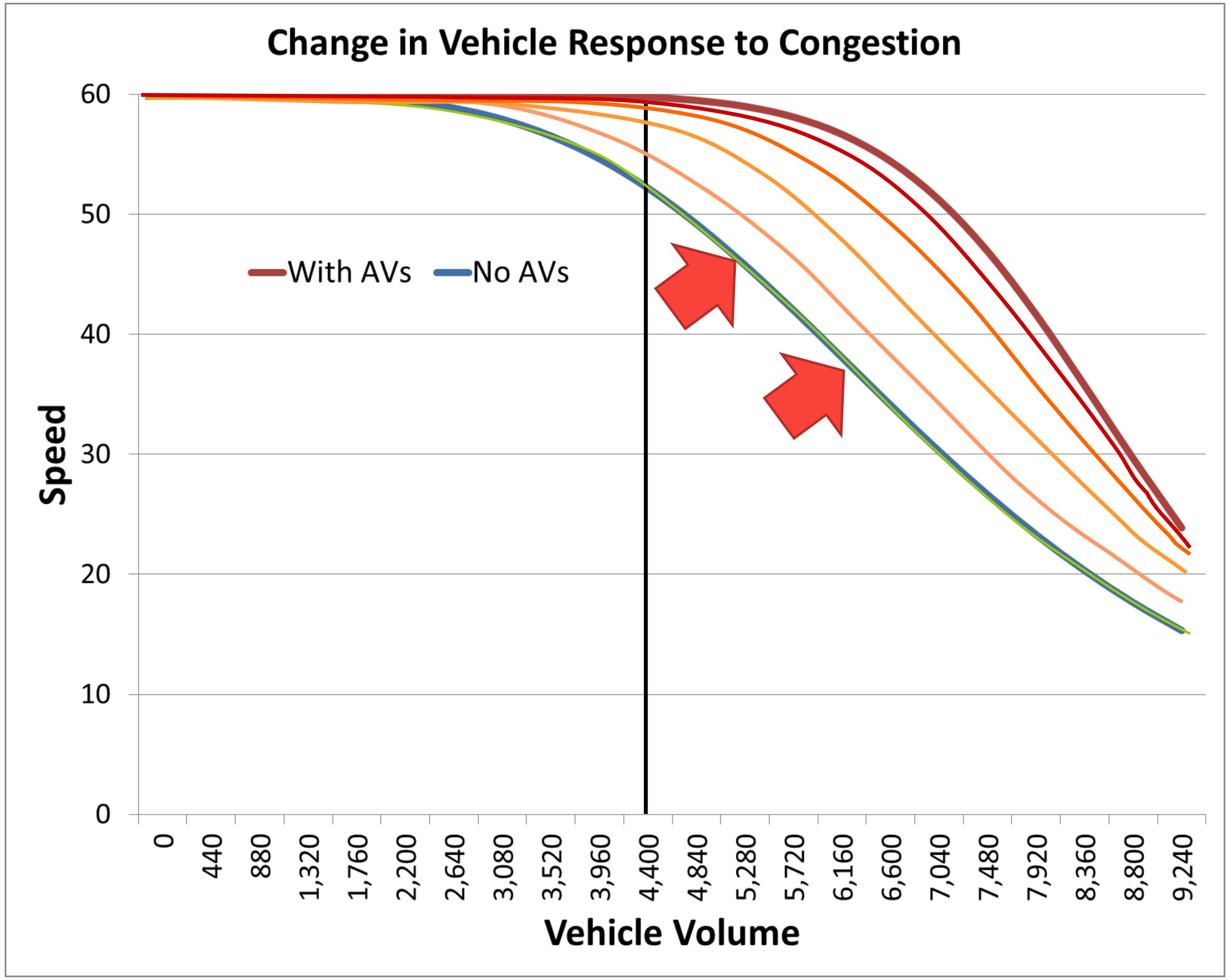
Capacity Adjustment

- **AV use will increase capacity by**
  - *Ability to maintain shorter headways on freeways and express ways*
  - *AV's have the ability to mitigate the effects of congestion on travel time*
- **Model Adjustments** ***– Owned & Shared Scenarios***
  - *Increase capacity by 50% for freeways and expressways*
  - *Increase capacity by 10% for Arterials*
  - *Modify the relationship between volume and speed to be more "forgiving" with regard to demand*

Capacity Adjustment for AVs



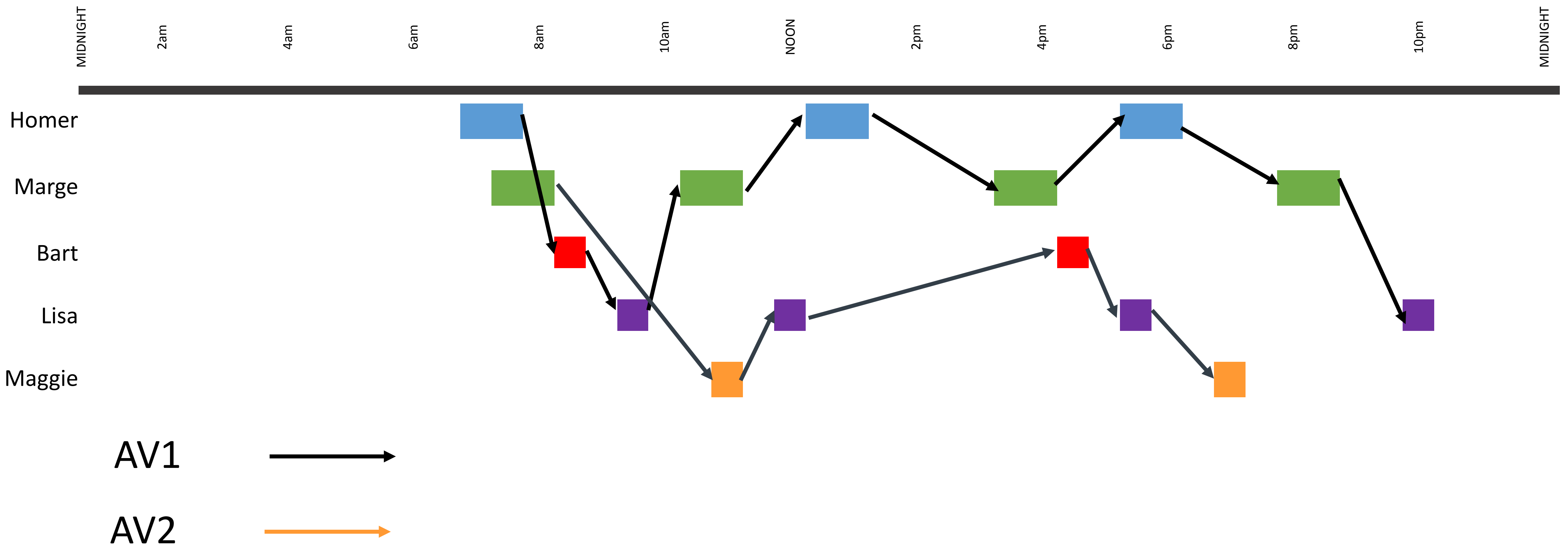
Adjusting Volume-Delay Functions



Driverless Vehicle Movements for Ownership Scenario, Activity-Based

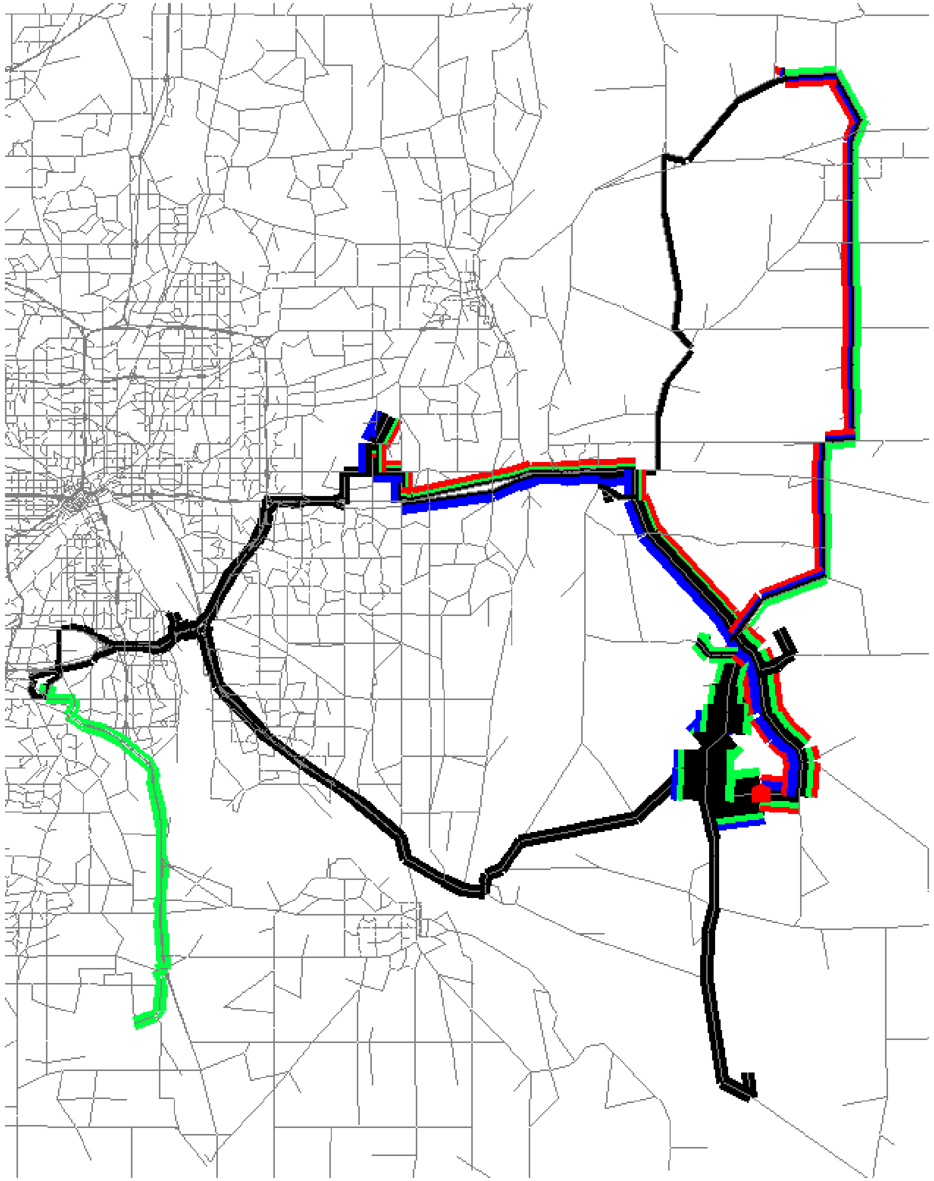
- Consider all model-estimated vehicle trips for each household, including origin, destination, start and end times
- Create an AV, and connect household vehicle trips sequentially through the day
- Consider time necessary for each driverless trip, and compare with available time
- In some cases consider intermediate parking
- Continue to create new AVs until all household trips are served

Driverless Vehicle Movements for the Ownership Scenario



Example:
Owned Vehicle,
Household 195302
Home Zone 2881

26 Occupied Trips
3 vehicles
Vehicle 1: 9 DL trips
Vehicle 2: 4 DL trips
Vehicle 3: 2 DL trips



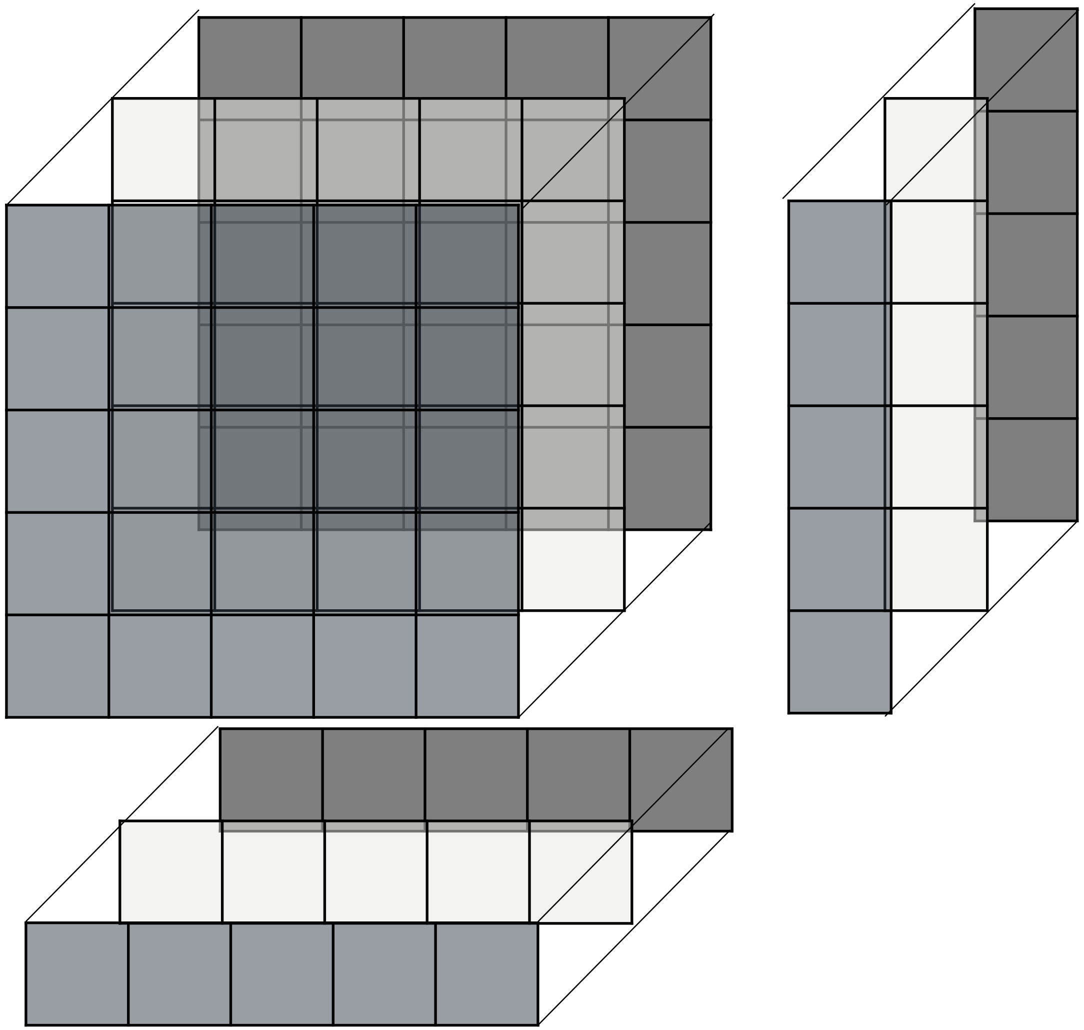
Driverless Vehicle Movements for Sharing Scenario, Trip-Based

- K-factors used to prohibit/discourage unreasonable trips in time
- Time-Stratified Skims are used to compute when connections cannot be made in time
- Balancing is done separately for both Start and end of driverless trip so we can see where and when surplus vehicles might occur – Driverless trip ends must be satisfied, however
- Matrix balancing uses a steep Friction factor curve to encourage short trips
- Apply a maximum time was imposed

Driverless Vehicle Movements for Sharing Scenario – Trip Based

3-Dimensional Matrix Balancing

- Trip Starts x
- Trip Ends x
- Time



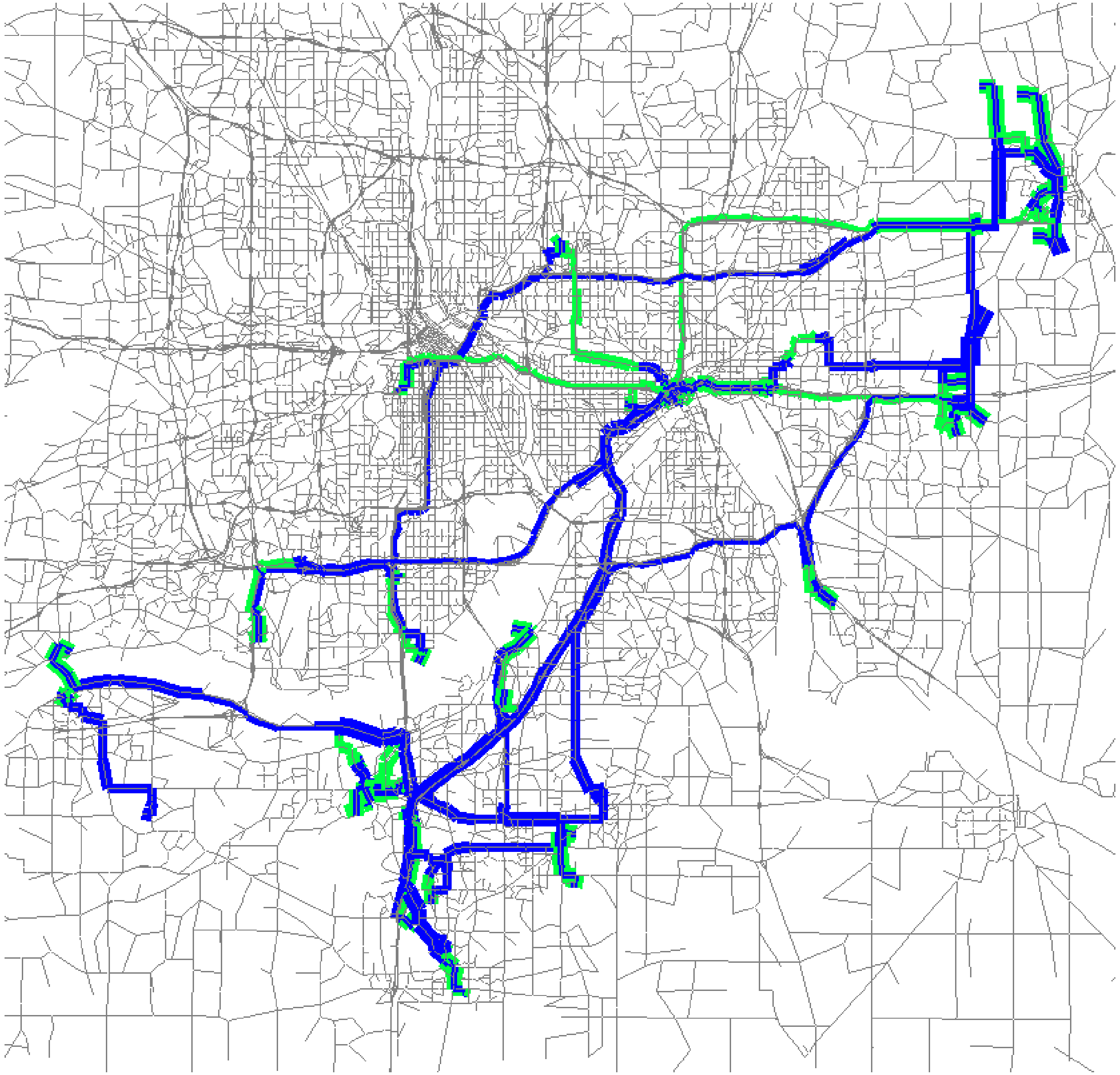
Driverless Vehicle Estimation: Activity-Based Model

- Same principal as used for ownership scenario – except all occupied vehicles are open to being served
- Search pattern seeks to minimize driverless trip time between services, and dwell time.
- User specifies a minimum and maximum dwell times
- User specifies maximum trip time
- Result is a set of driverless vehicle trip records, and a log of each vehicle’s movements throughout the day

Example:
Shared Vehicle 6316

30 Occupied Trips
29 Driverless Trips

292 Occupied Miles
115 Driverless Miles



Assignment of Driverless Vehicles

— Added driverless vehicles as an additional class –

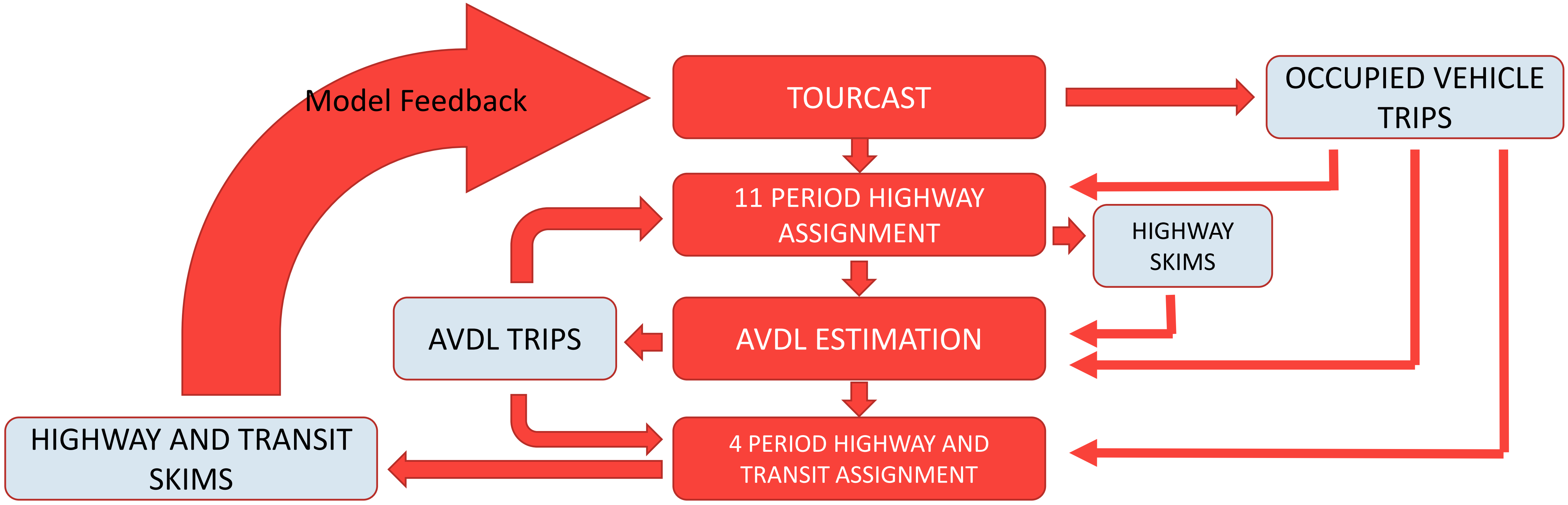
— Subsequent data available to plot where AVs would dwell when not in use.

— End of Day re-positioning possible

— Wealth of MOE's available for both occupied and driverless vehicles

— Feedback ensures that congestion imposed by driverless vehicles influences other behavior

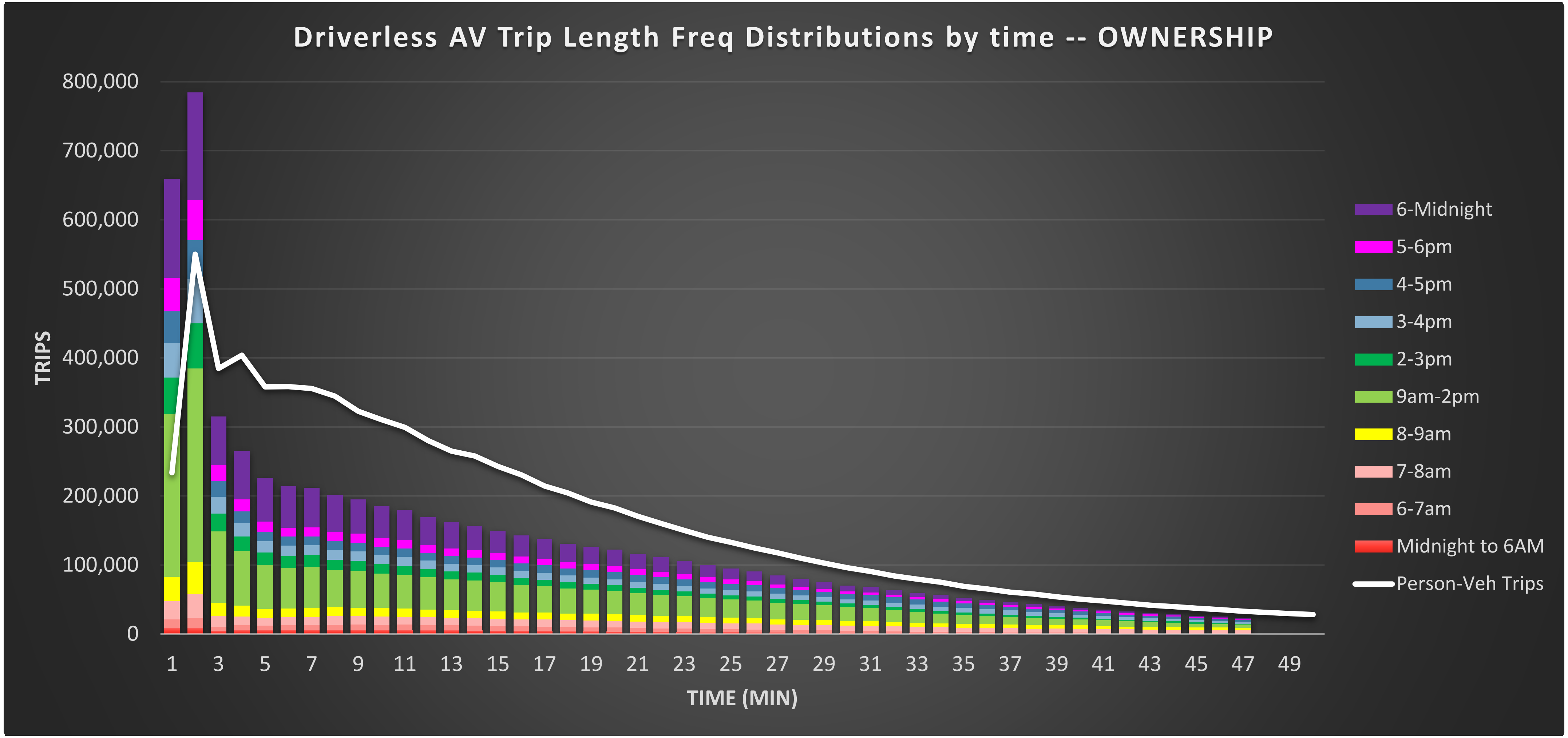
Autonomous Vehicle Model Flowchart – Twin Cities ABM



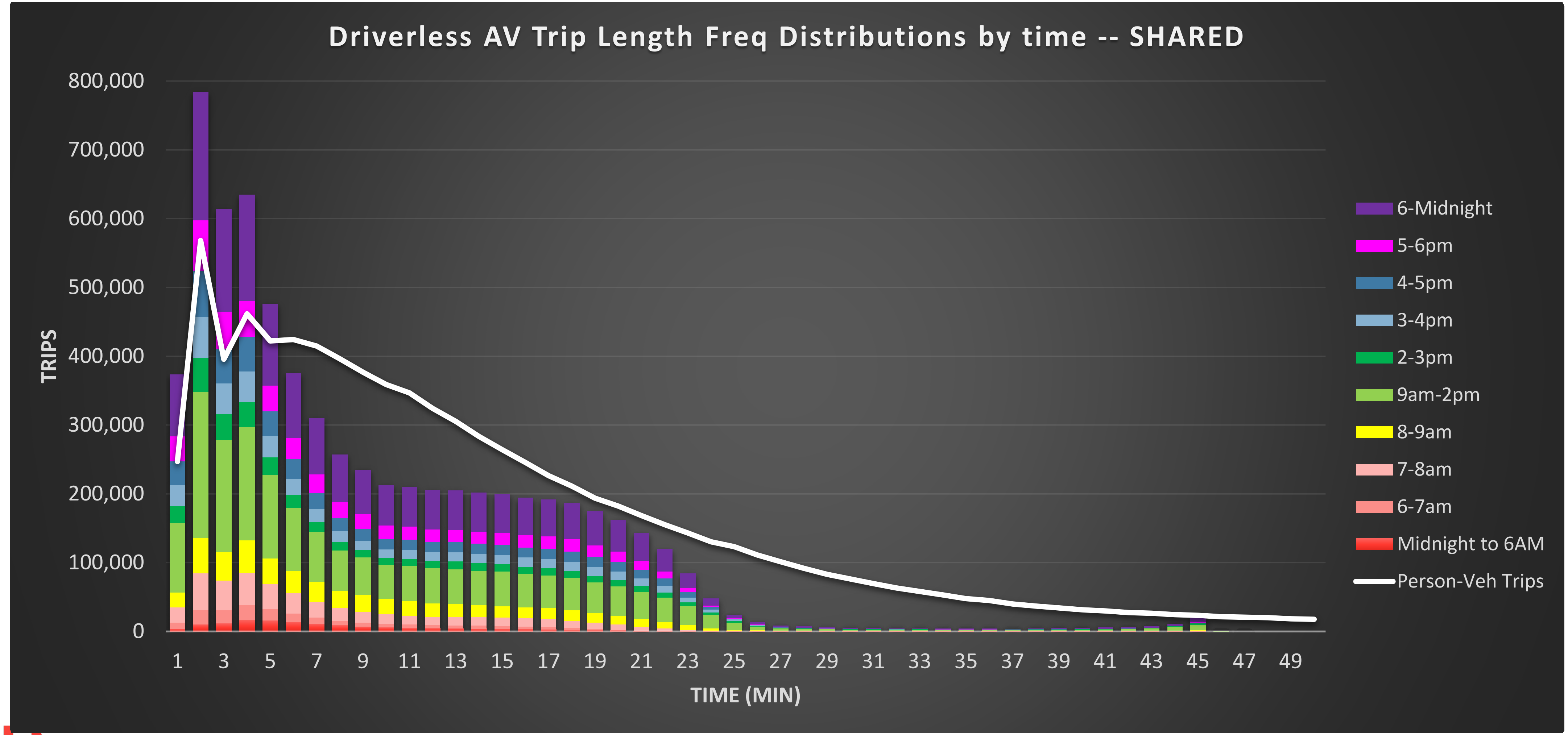
8. Examples of Results that are Available

- Trip Length Frequency Distribution
- Efficiency of Use by Shared AVs
- Map of Household use of Shared vs. Owned AVs
- VMT by Level of Service by Scenario
- End of Day Vehicle Re-positioning Map

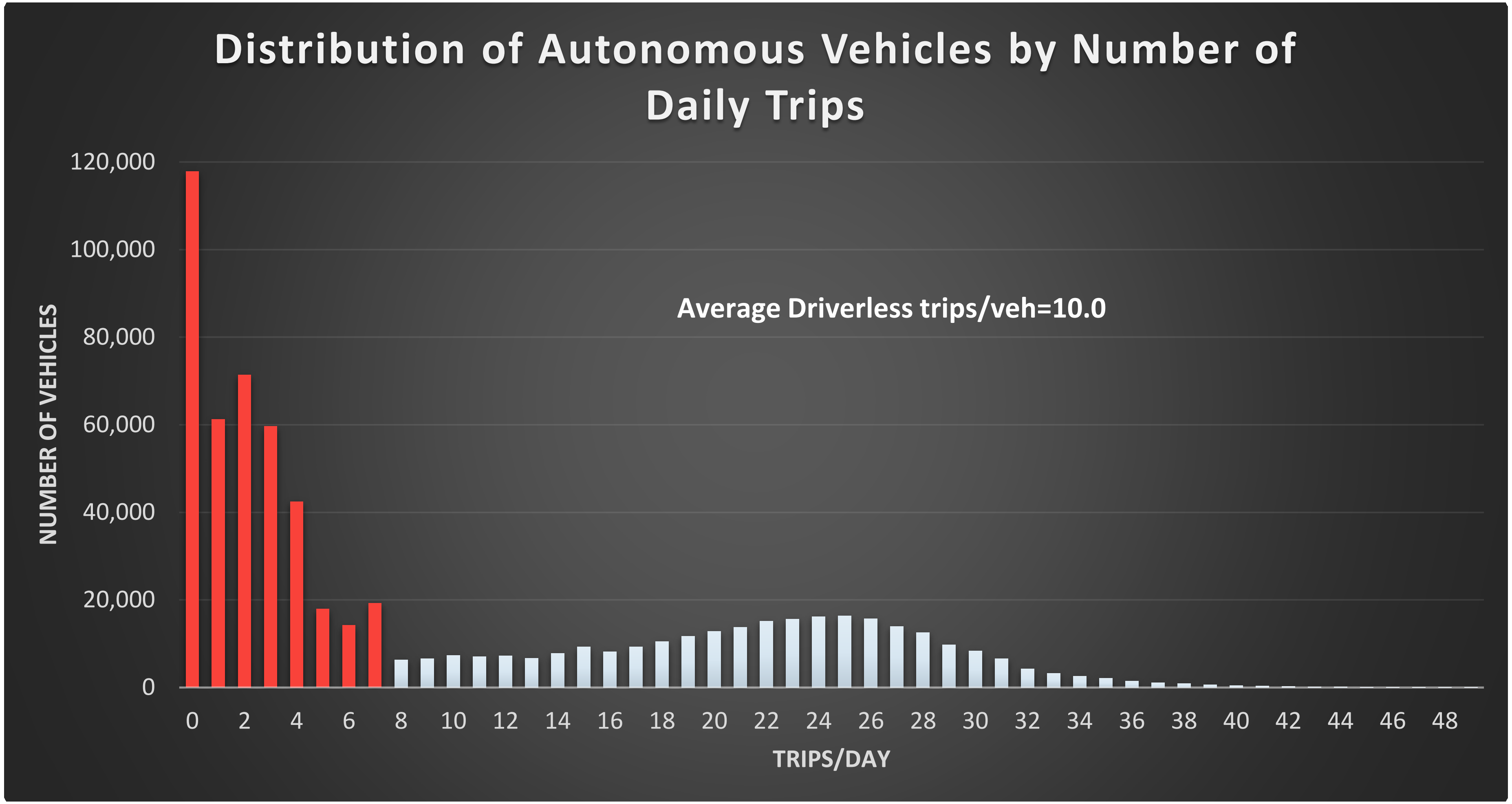
Ownership Scenario Driverless Trips by Vehicle



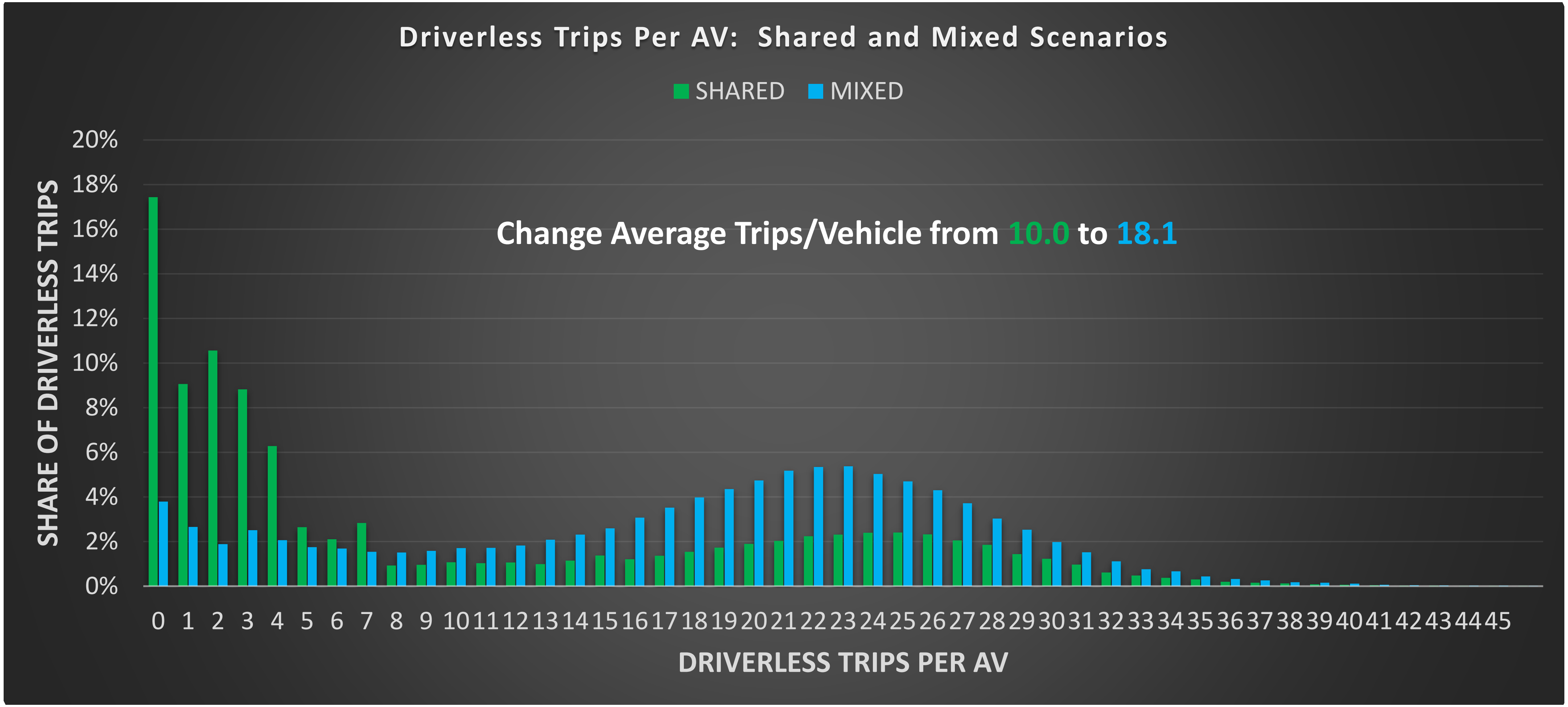
Shared Scenario Driverless Trips by Vehicle



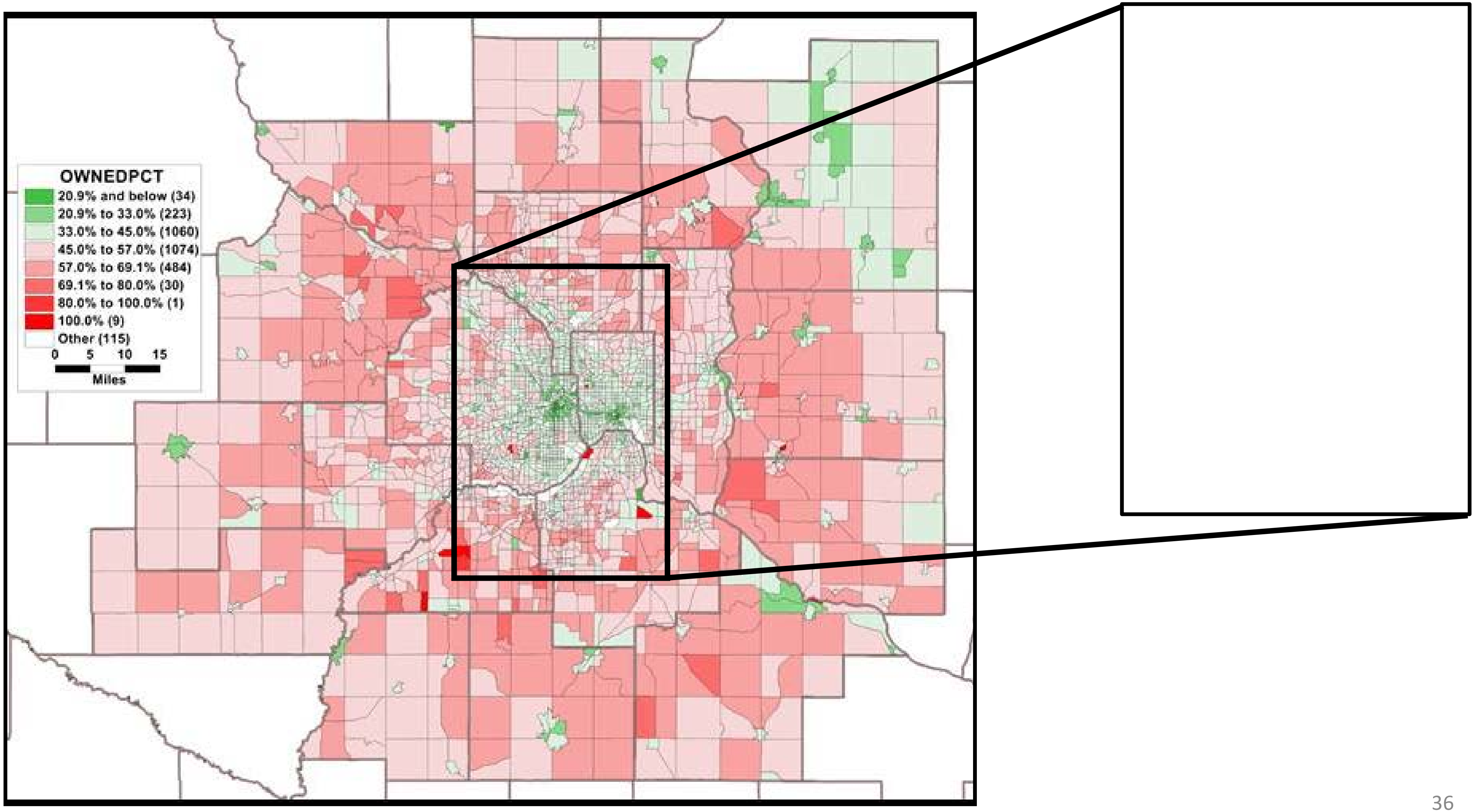
Shared Scenario Driverless Trips by vehicle



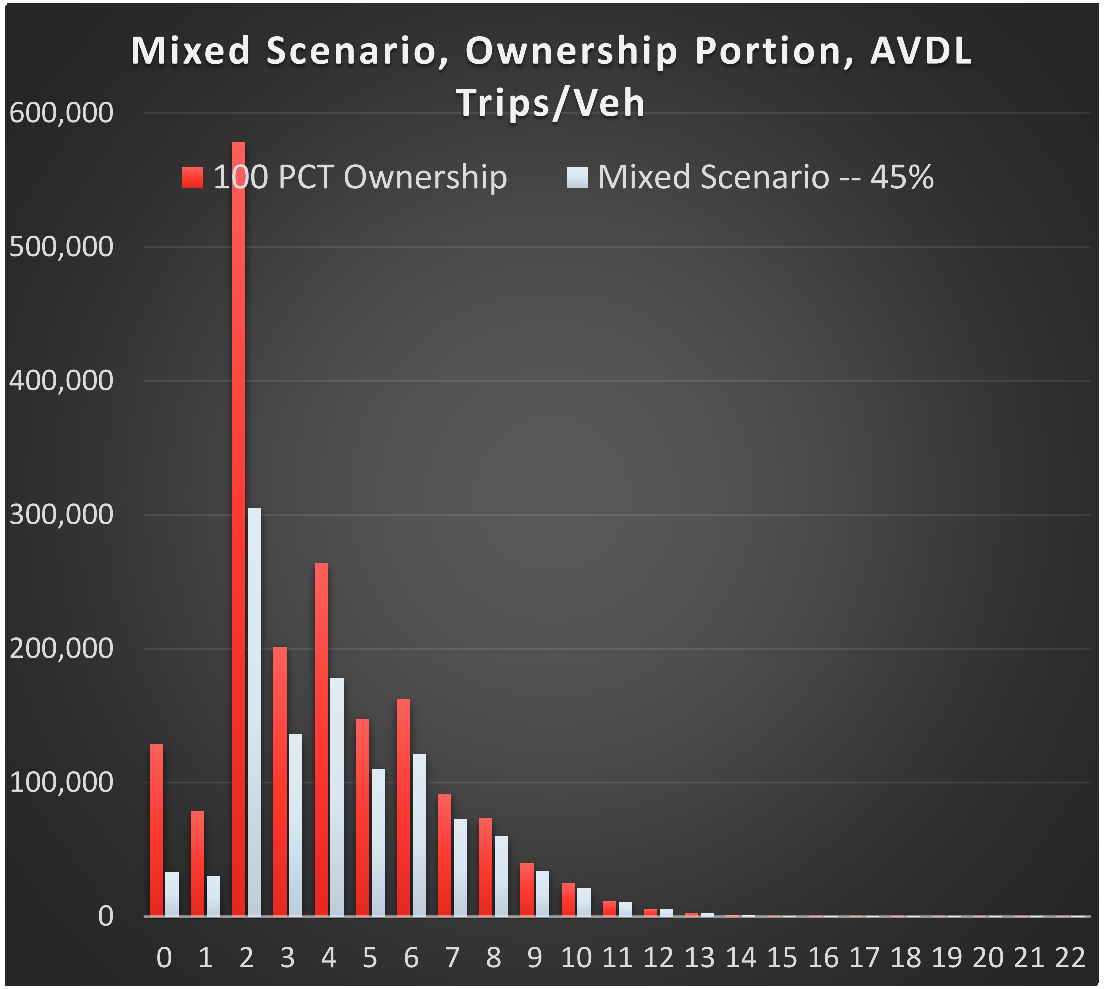
Change in Shared Scenario Driverless Trips by Vehicle

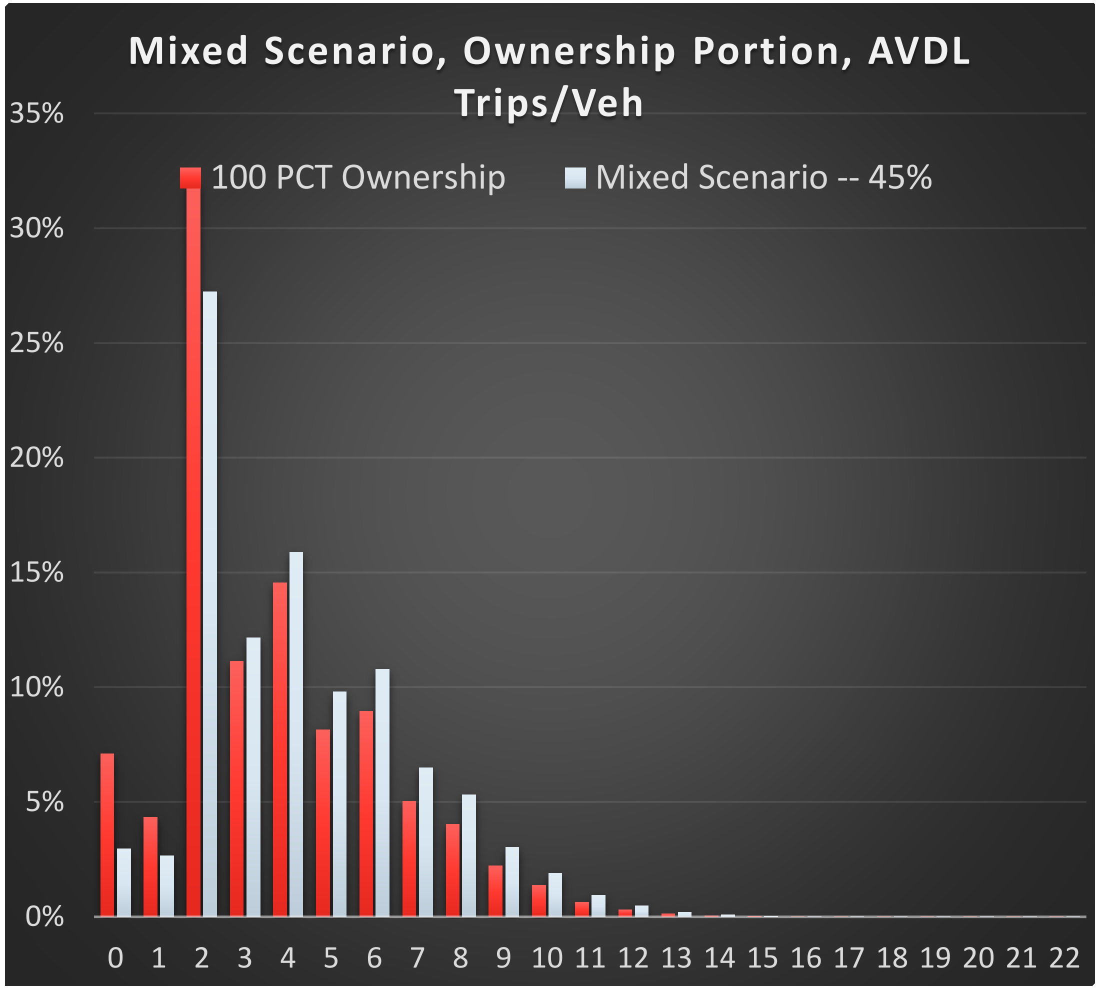


Map of Zones by Share of Households Owning AVs

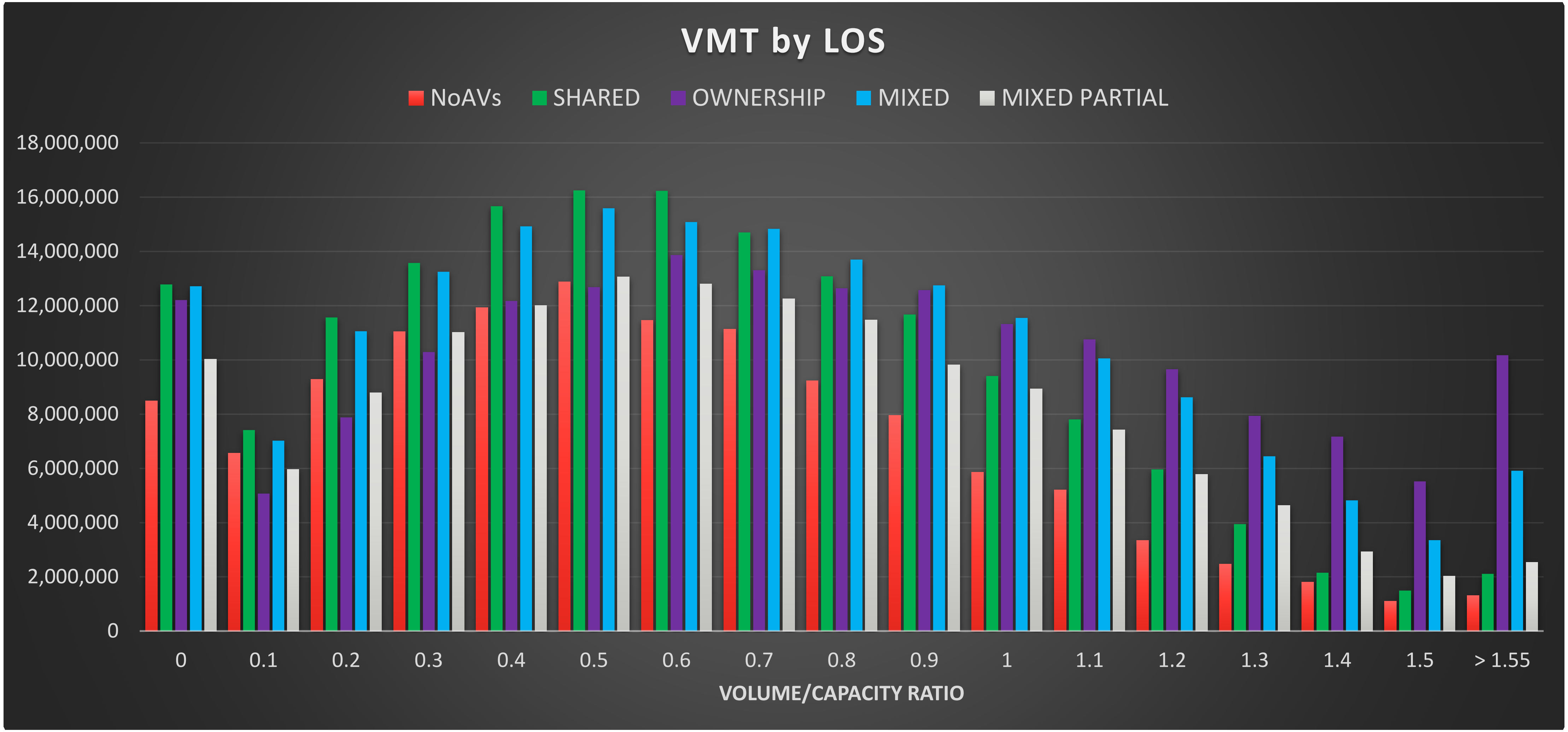


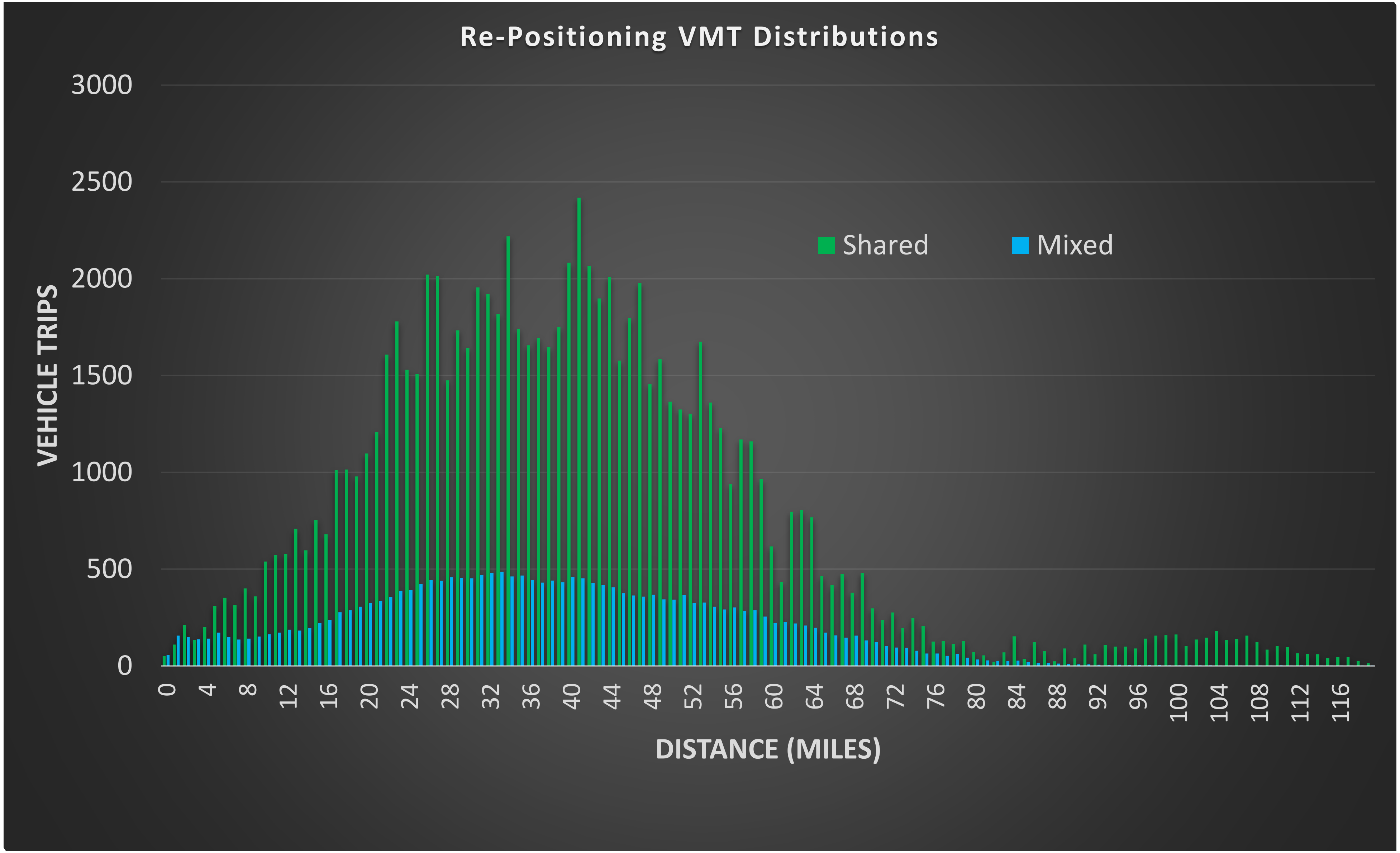
AVDL/AV – Mixed and Ownership



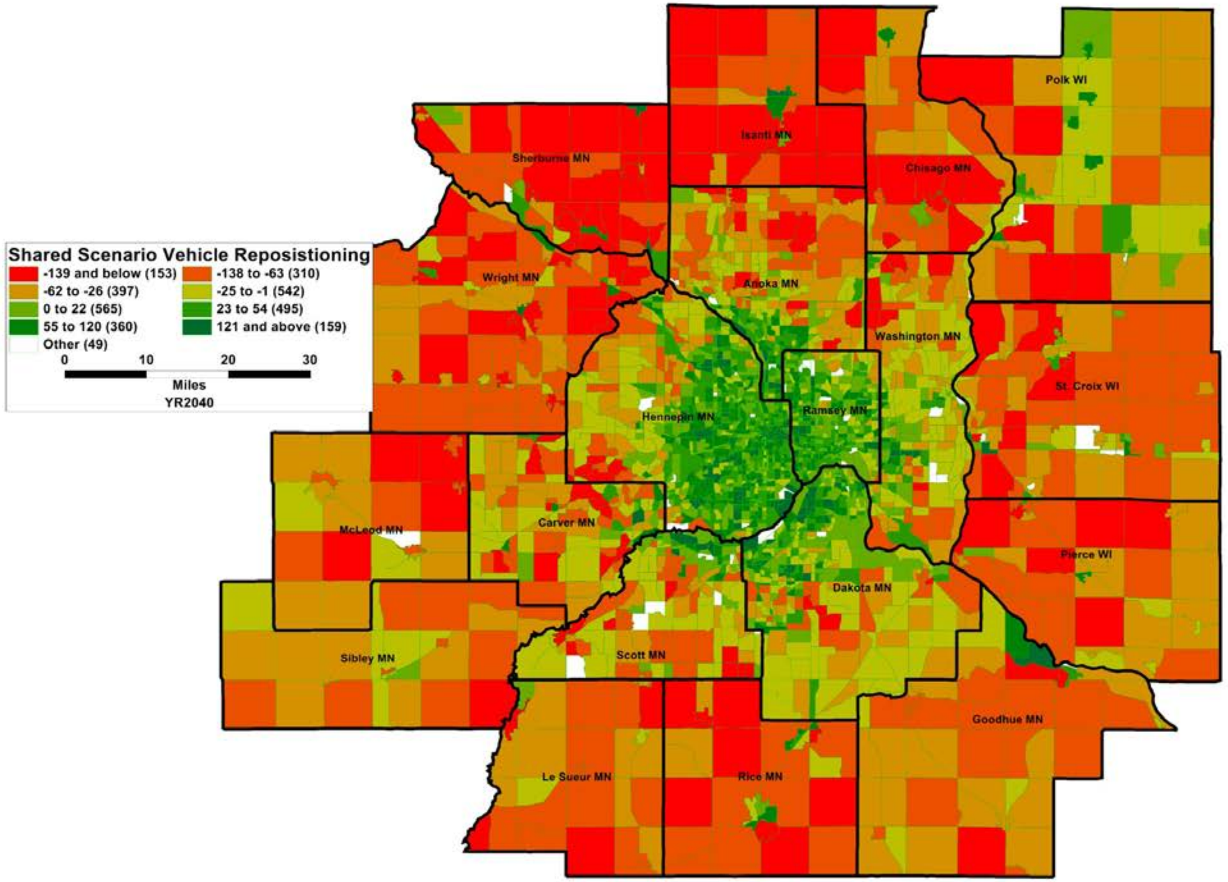


VMT by Level Of Service

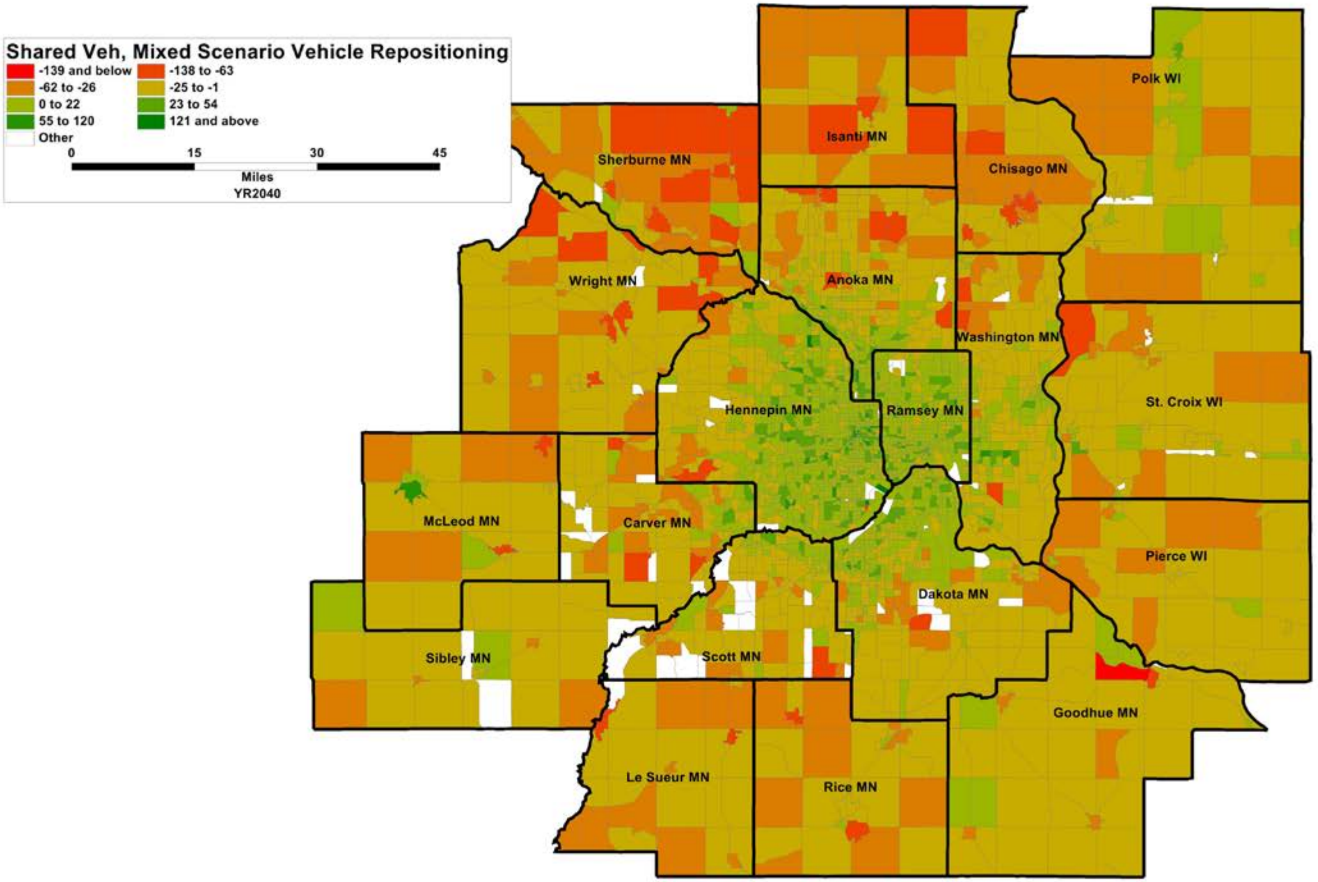



Re-Positioning VMT Distributions
Shared
Mixed
VEHICLE TRIPS
DISTANCE (MILES)
0
500
1000
1500
2000
2500
3000
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
68
72
76
80
84
88
92
96
100
104
108
112
116

Shared Vehicle Repositioning – Shared Scenario 3.6M VMT, 64K VHT

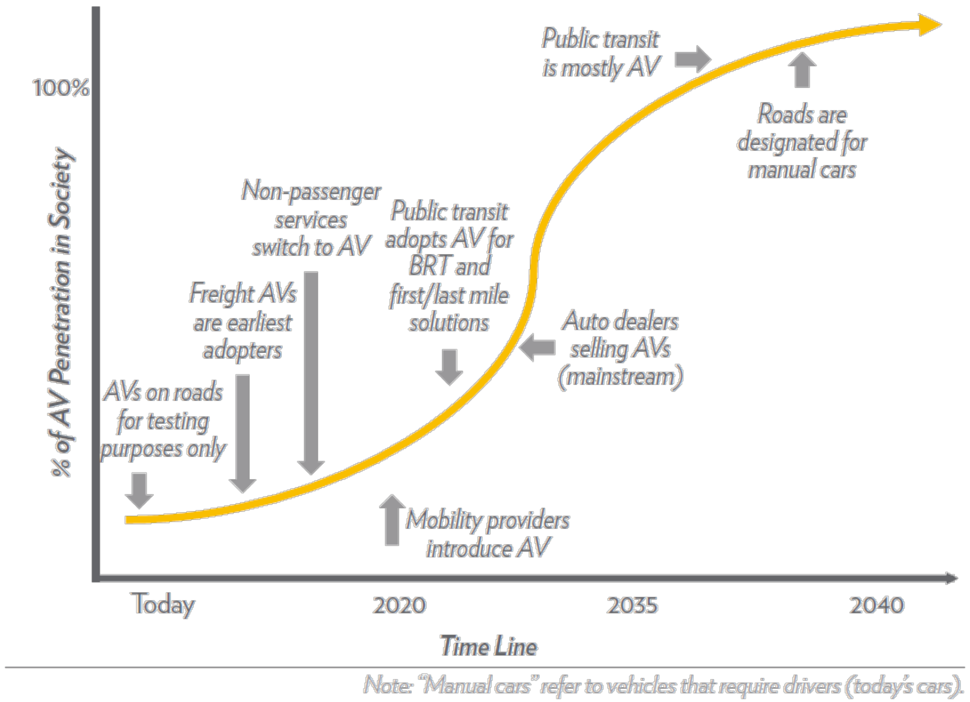


Shared Vehicle Repositioning – Mixed Scenario
0.9M VMT, 15K VHT



9. Research That is Needed

- AV Driving Characteristics
- Vehicle Capital Cost for each scenario
- Vehicle Operating Cost for each scenario
- Behavioral Changes for
  - *Former non-drivers*
  - *Activity pattern changes as a result of AVs*



Isaac, Lauren, "Driving Towards Driverless: A Guide For Government Agencies. WSP|Parsons Brinckerhoff. 2016. Page 13.

Questions?