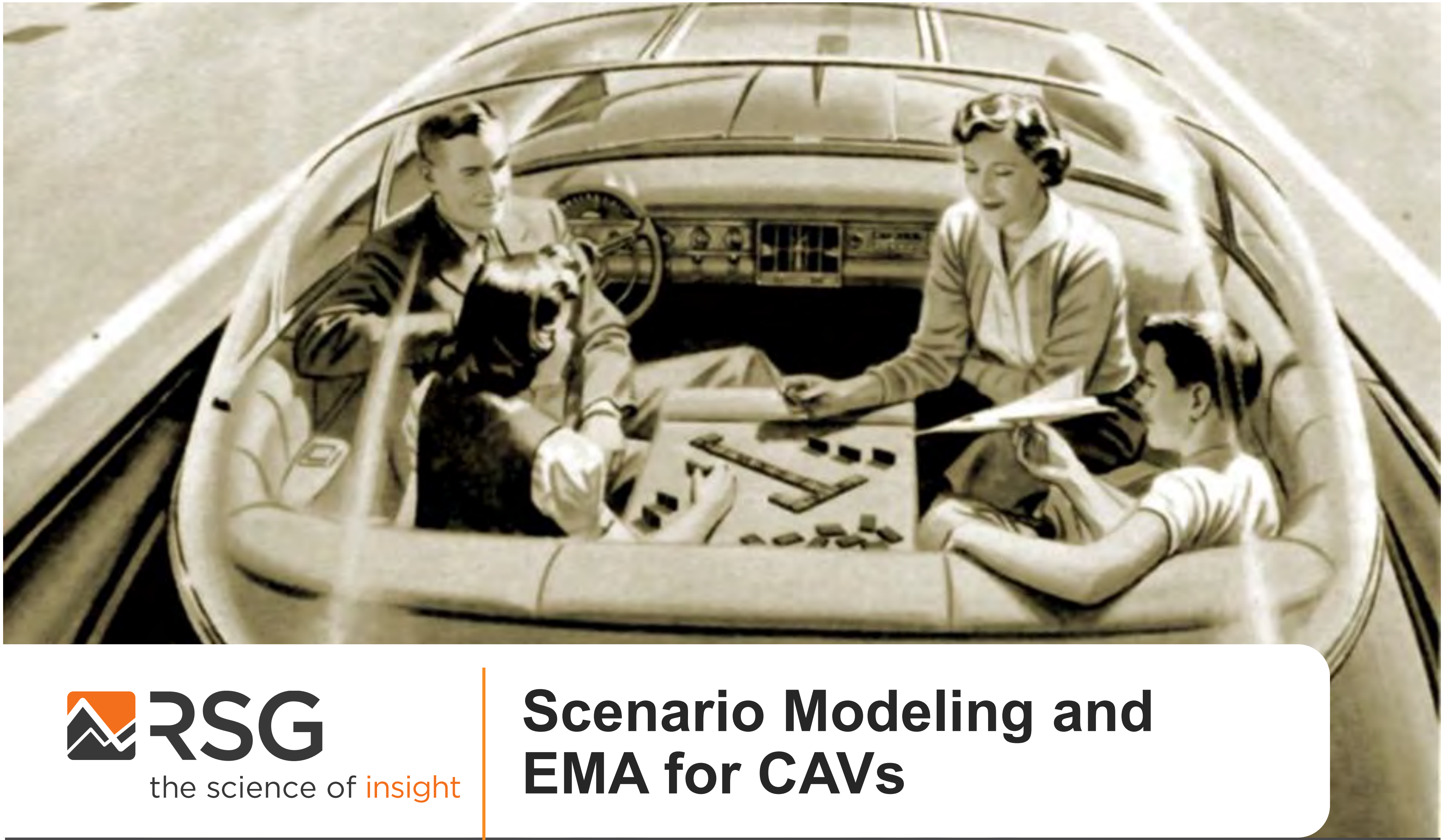


RSG
the science of insight

Scenario Modeling and EMA for CAVs

Vince Bernardin, PhD

February 28, 2019

“All models are wrong, but some are useful.”

– George Box, famous statistician

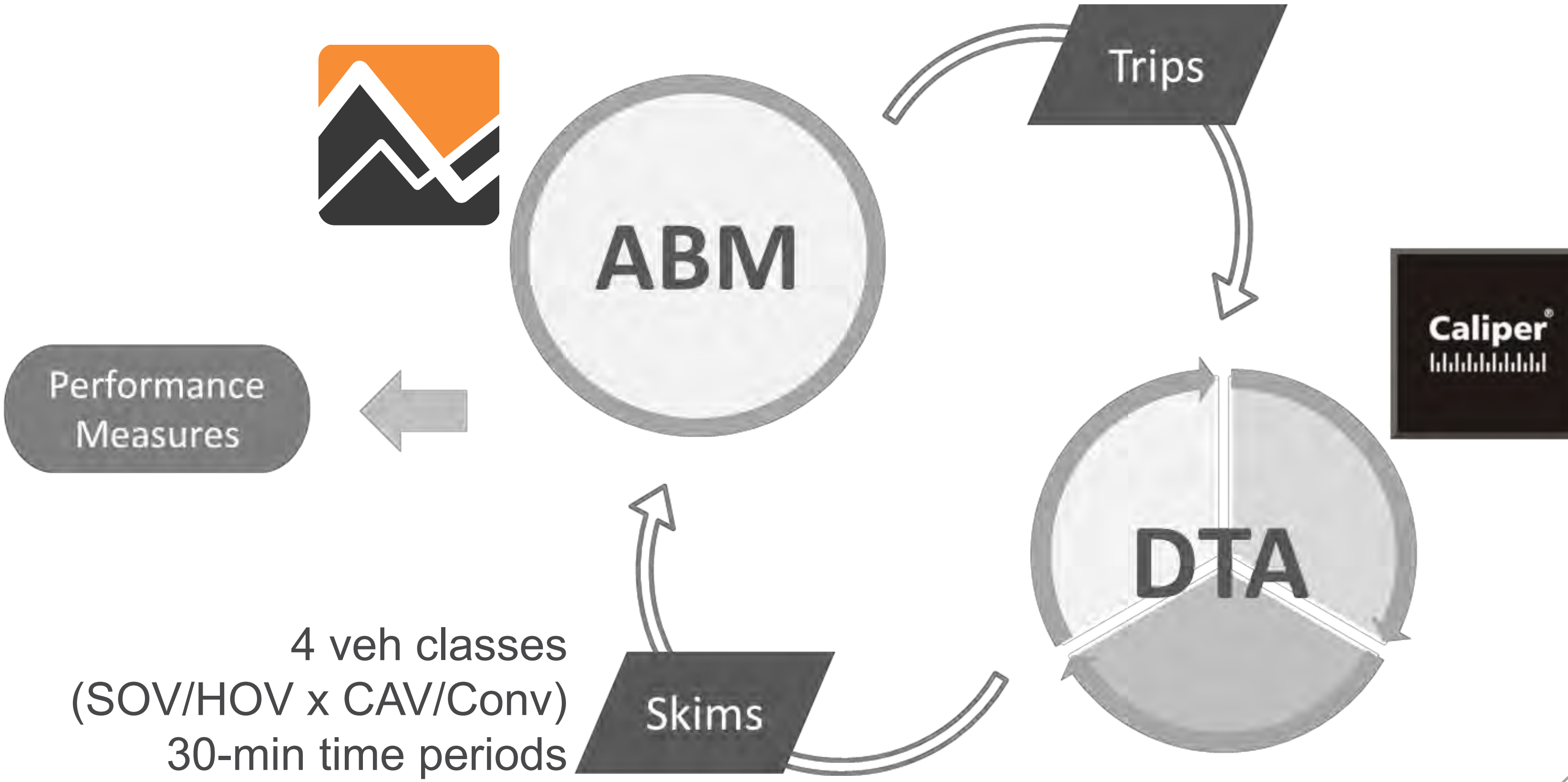
How can models be USEFUL in planning for CAVs?

- Scenario Planning
  - structured way for organizations to think about the future using a limited number of scenarios (e.g., best case, worst case, most likely, etc.)
- Exploratory Modeling Analysis (EMA)
  - simultaneously vary input assumptions across a wide range of future scenarios along key dimensions of uncertainty
  - to explore potential outcomes, find critical input assumptions, and identify future policy directions likely to be robust in the face of “deep uncertainty”

EMA with ABM-DTA

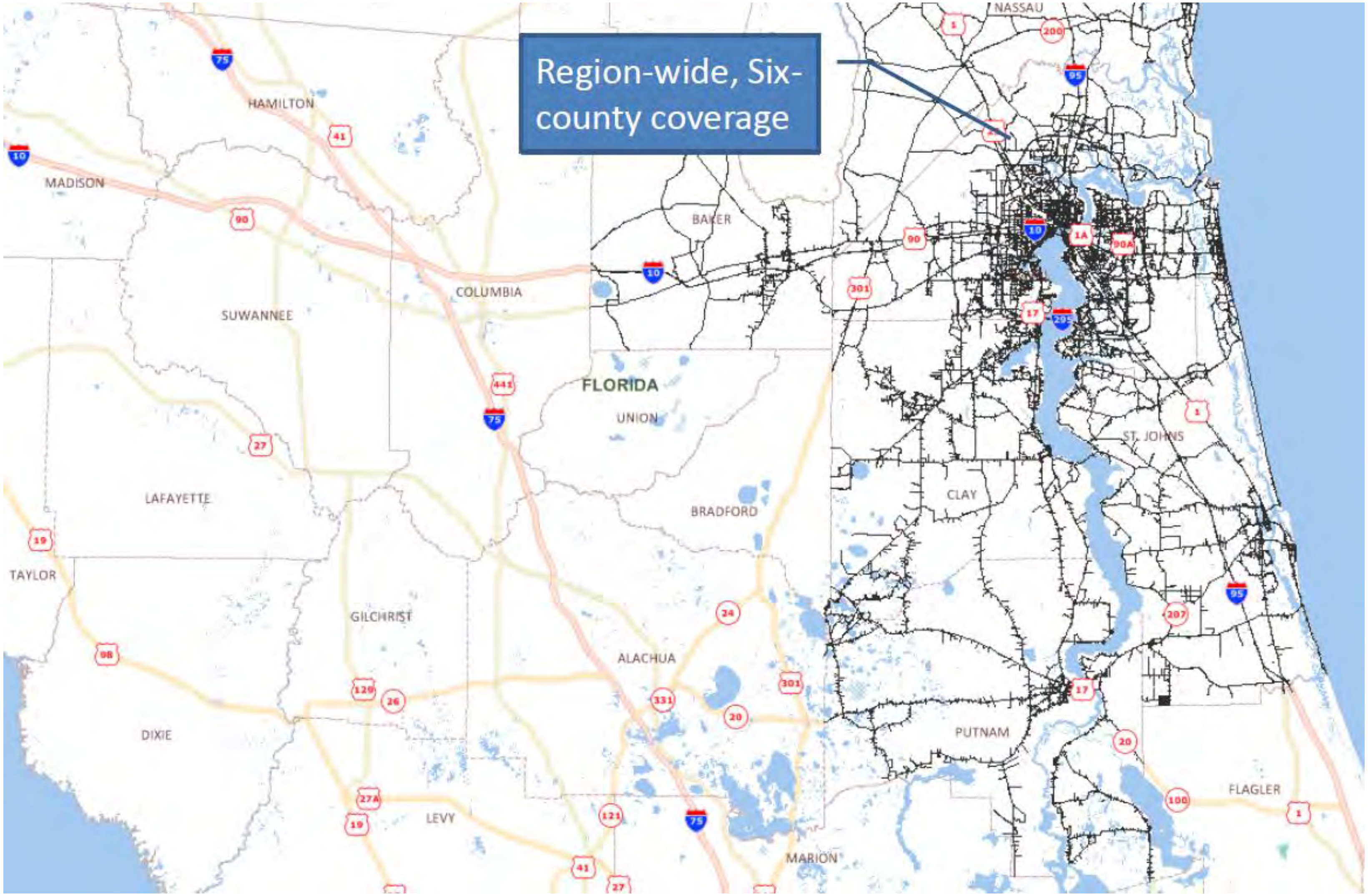
Jacksonville EMA Study

- Combined ABM-DTA model
- “loose coupling” via skims



4 veh classes
(SOV/HOV x CAV/Conv)
30-min time periods

Jacksonville Model Overview



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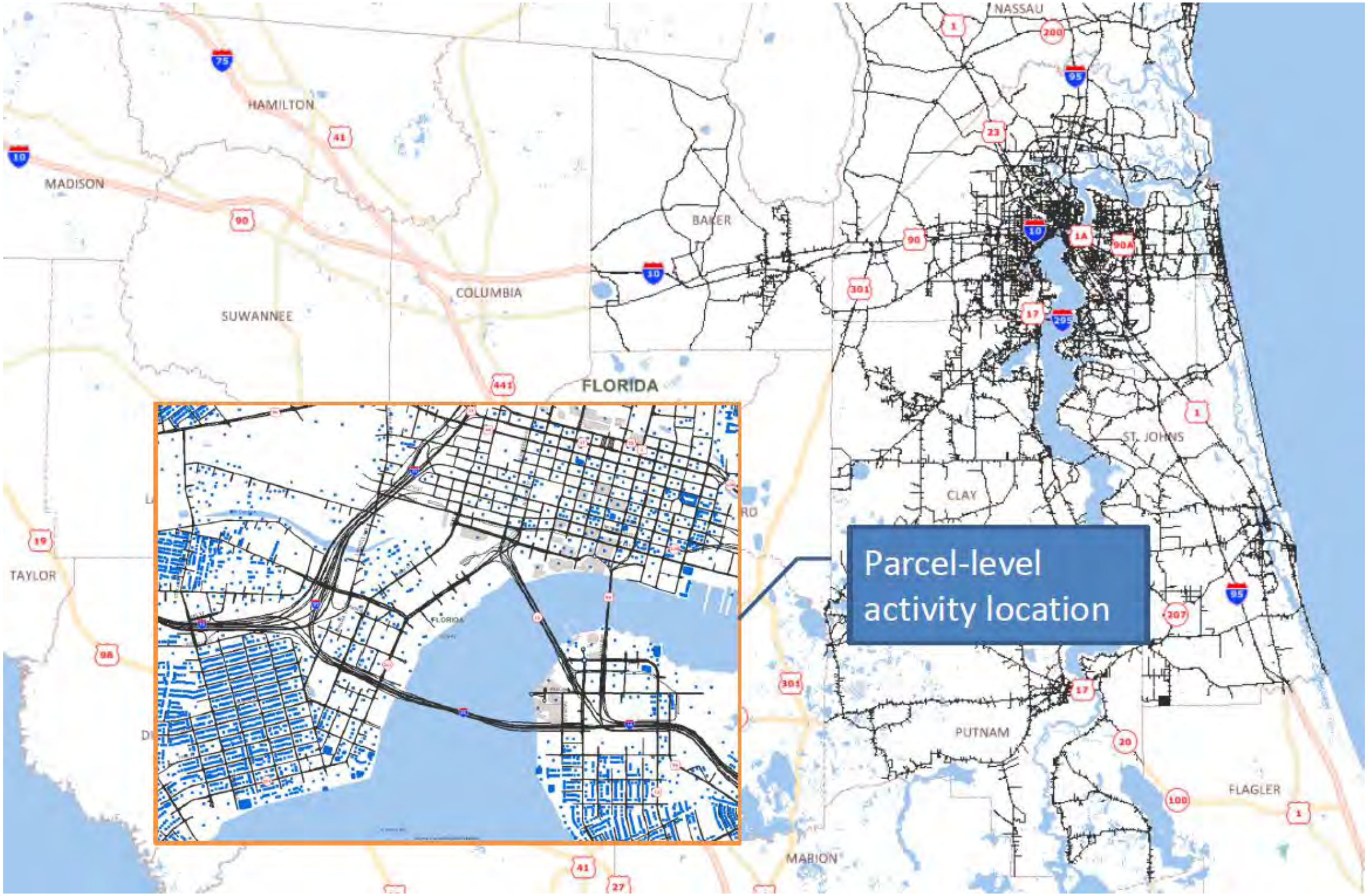

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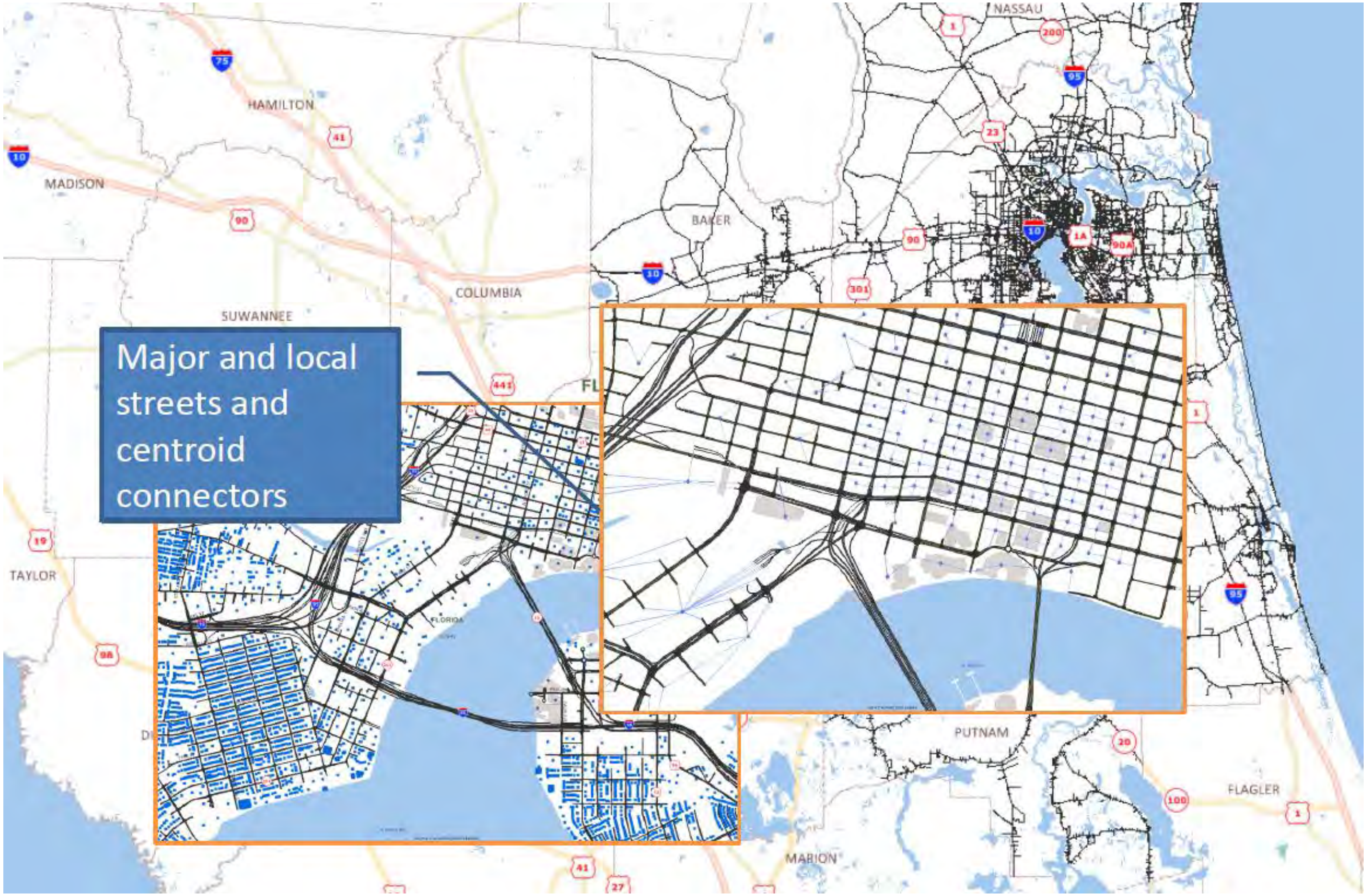

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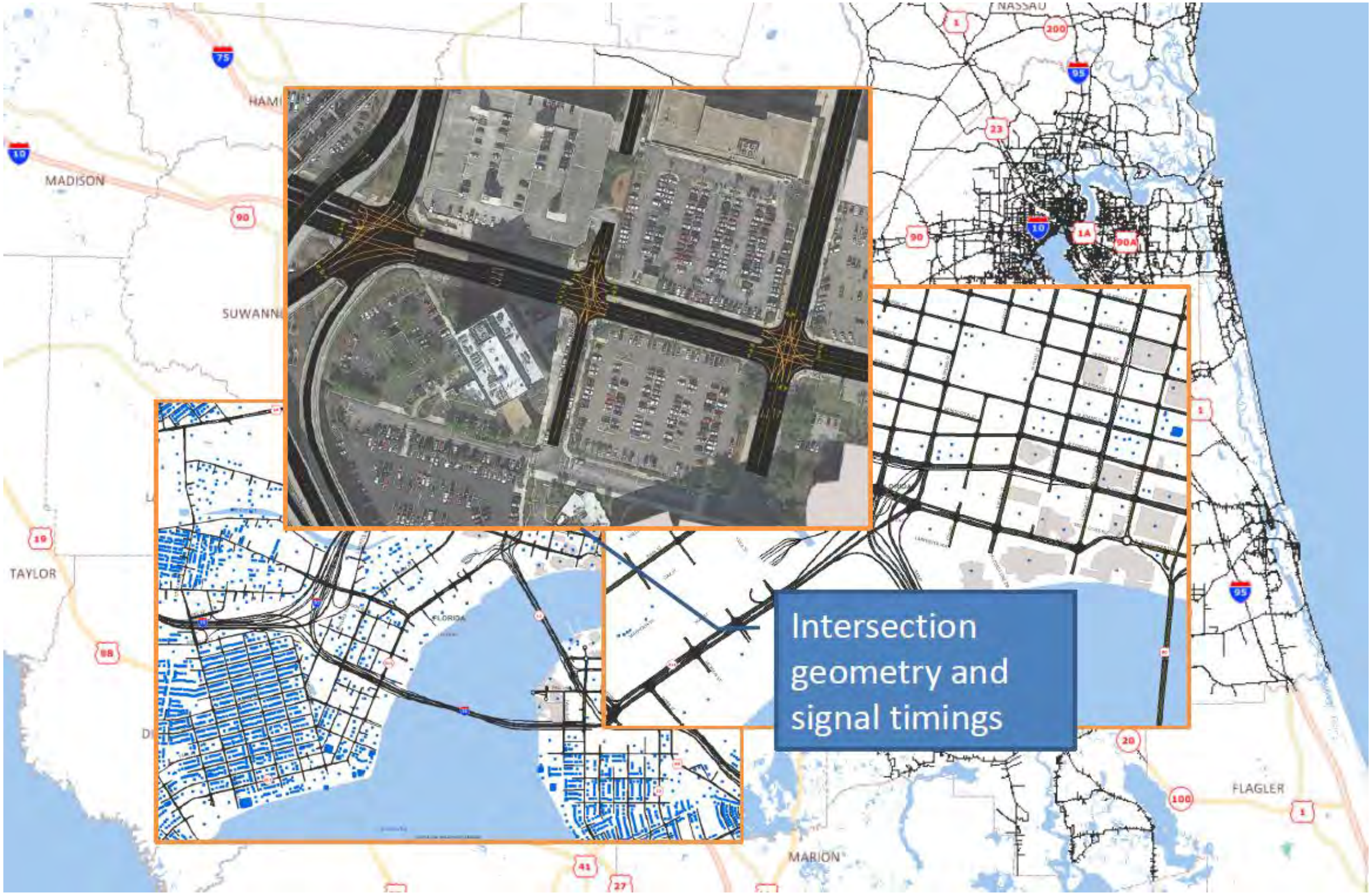
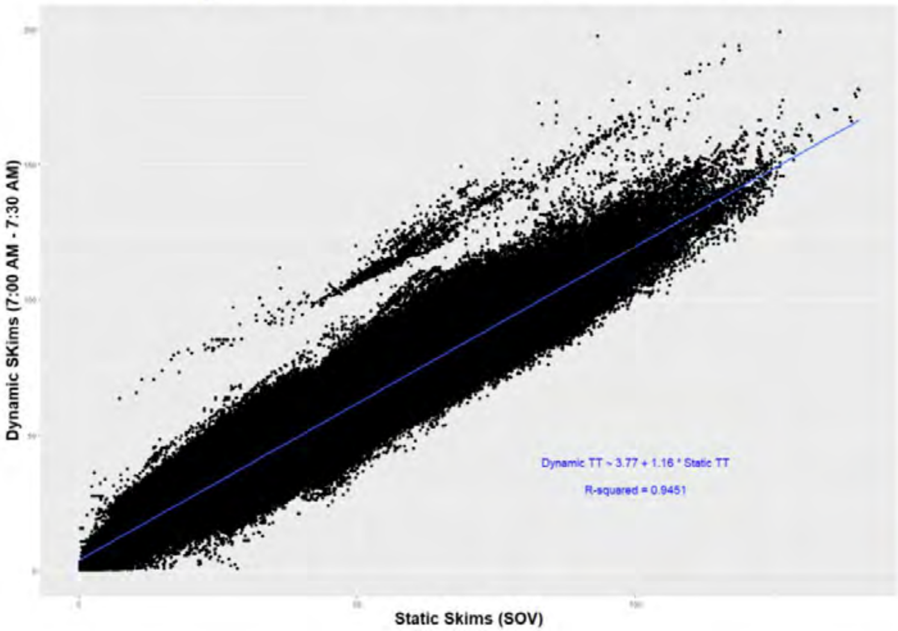
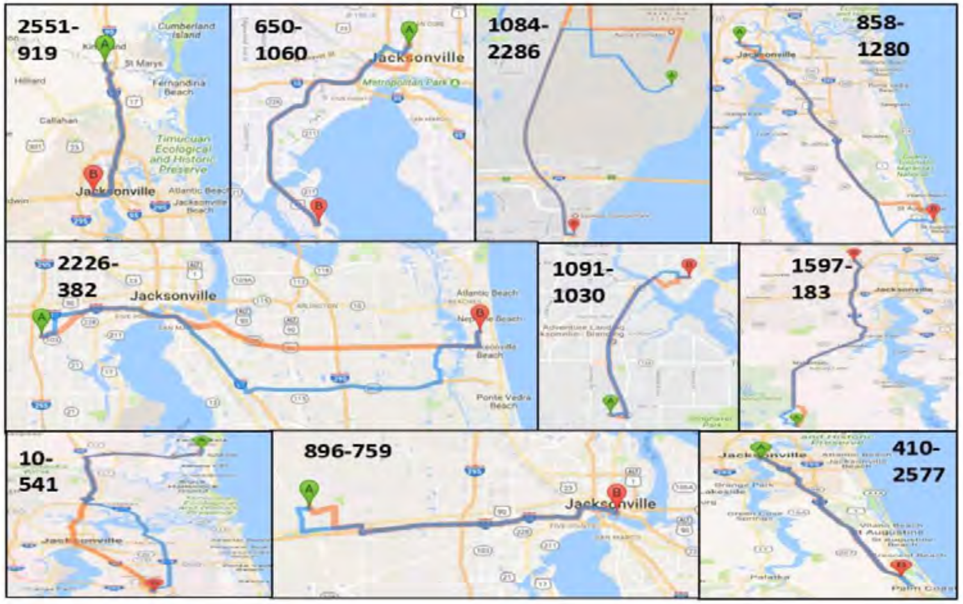


Validation of Dynamic Skims

Dynamic versus static



Outlier review



Model Runtime Performance

- Windows machines with 12 cores
  - TransModeler DTA: 5 - 9 AM, 25 iterations → 24 hours
  - DaySim ABM → 45 min
  - DaySim using AM dynamic skims + transpose for PM peak and static assignment for midday and night periods
  - Ran 3 to 5 feedback loops
  - Transit skims held constant
- Runtimes limited the number of EMA runs that could be done

CAV Enhancements to Daysim

- Auto ownership model includes choice between conventional and autonomous private vehicles
- The “paid rideshare” (TNC) mode added to mode choice
- TNCs can be specified to use AVs
- AV passengers can have lower disutility of travel time
- Use separate auto skim matrices for AVs
- ZOV Trips NOT included

CAV Enhancements to TransModeler

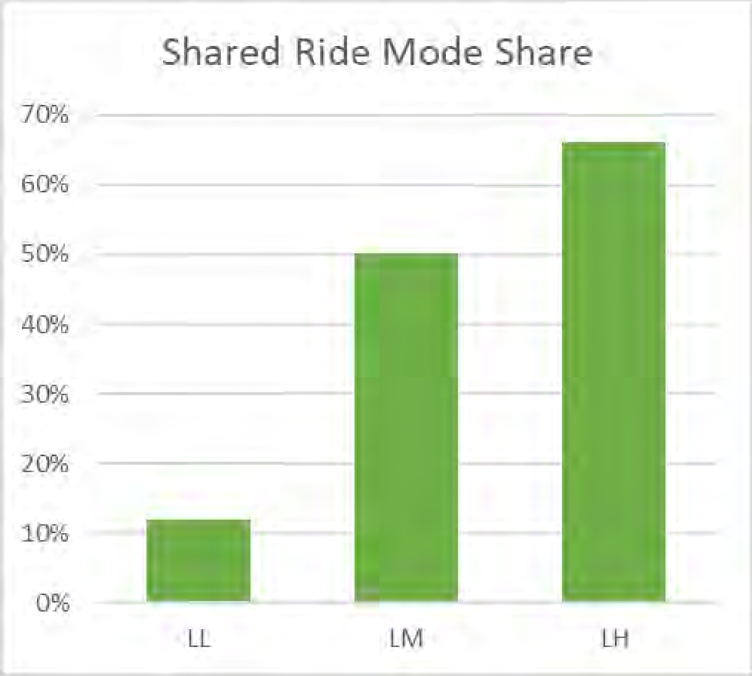
- Aspects of Driving Behavior Identified for Adaptation
  - Acceleration/deceleration
  - Car following headways
  - Choice of travel speed
  - Gap acceptance in lane changing
- Vehicle and Driving Behavior Assumptions
  - Removal of the random/human element from aspects controlled by the vehicle
  - Aspects deterministic, predictable, homogeneous

Experimental Design

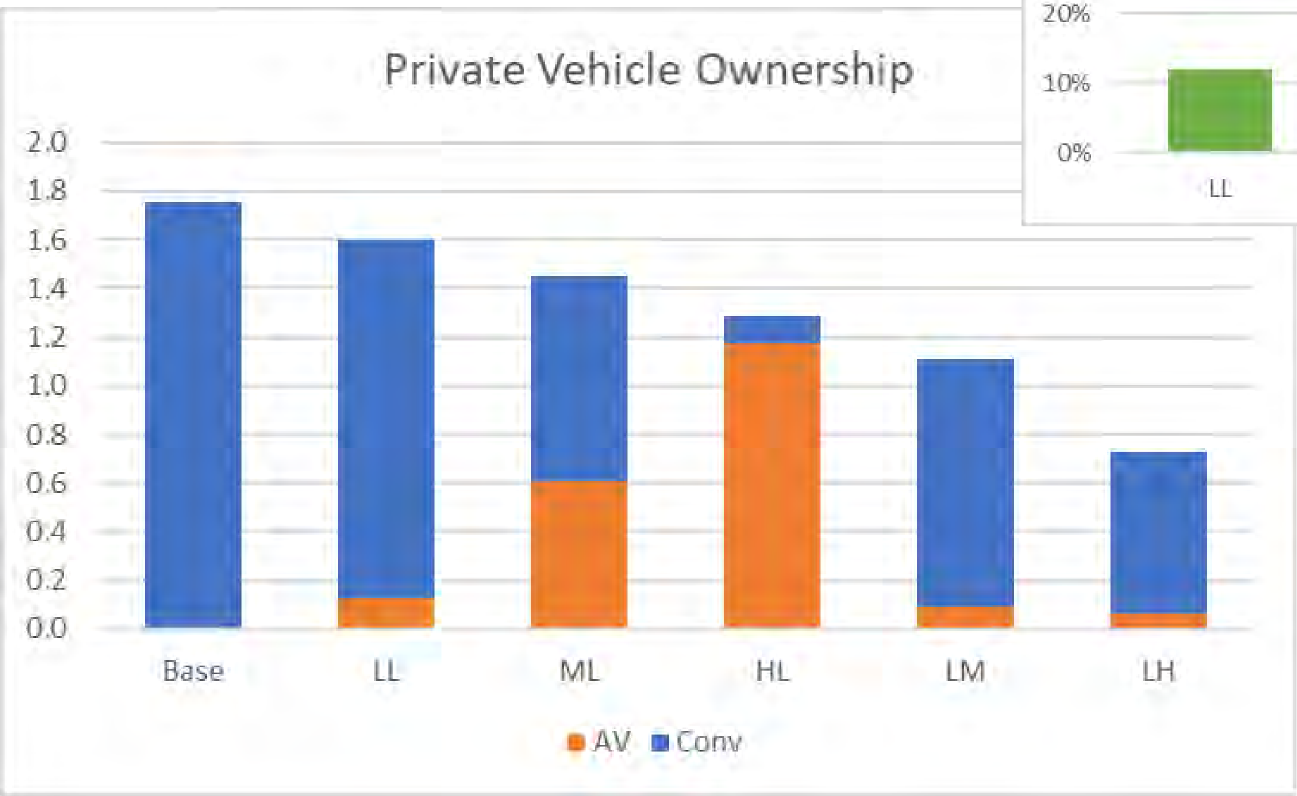
SCENARIO	PRIVATE AV ADOPTION	SHARED AV ADOPTION	RESERVED AV CAPACITY	AUTOMATION LEVEL
BB–N0	None	None	None	None
MM–L3	Medium	Medium	Interstate left lanes	Level 3
MM–AC	Medium	Medium	None	Level 3 + ACC
MM–LC	Medium	Medium	Interstate left lanes	Level 3 + ACC
MM–IC	Medium	Medium	Interstate all lanes (only inside the I 295 ring road)	Level 3 + ACC
LH–L3	Low	High	Interstate left lanes	Level 3
LH–AC	Low	High	None	Level 3 + ACC
LH–LC	Low	High	Interstate left lanes	Level 3 + ACC
LH–IC	Low	High	Interstate all lanes (only inside the I 295 ring road)	Level 3 + ACC
HL–L3	High	Low	Interstate left lanes	Level 3
HL–AC	High	Low	None	Level 3 + ACC
HL–LC	High	Low	Interstate left lanes	Level 3 + ACC
HL–IC	High	Low	Interstate all lanes (only inside the I 295 ring road)	Level 3 + ACC
HH–L3	High	High	Interstate left lanes	Level 3
HH–AC	High	High	None	Level 3 + ACC
HH–LC	High	High	Interstate left lanes	Level 3 + ACC
HH–IC	High	High	Interstate all lanes (only inside the I 295 ring road)	Level 3 + ACC

- SAE 3 +/- CACC
- Adoption
  - High
  - Medium
  - Low
  - None
- Split of Private vs. Shared
- CAV only lanes / freeways

Scenarios

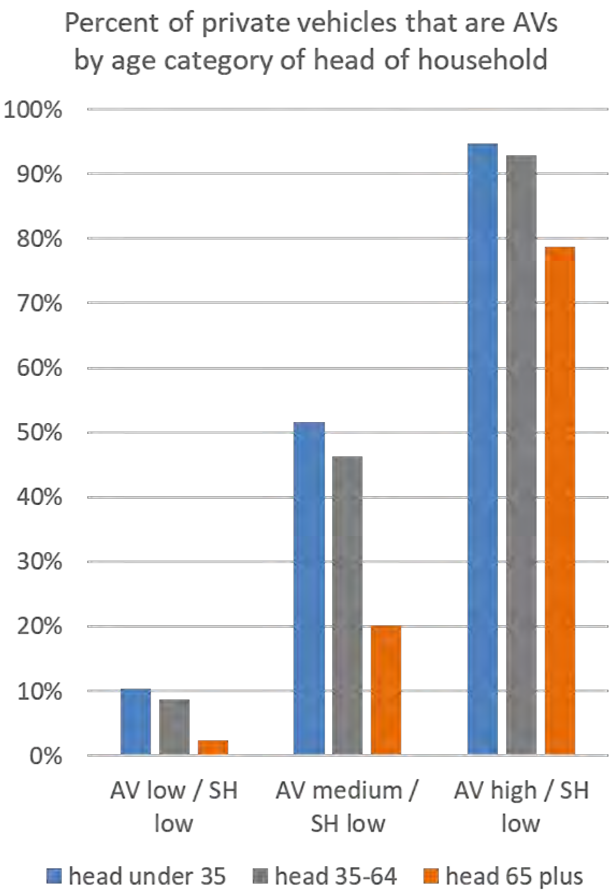


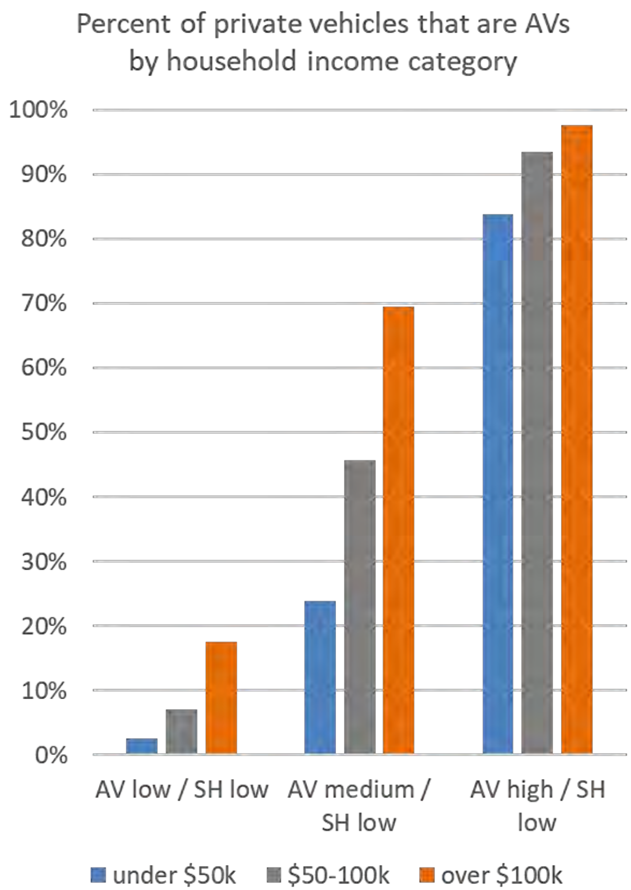
Shared Ride Mode Share
70%
60%
50%
40%
30%
20%
10%
0%
LL
LM
LH

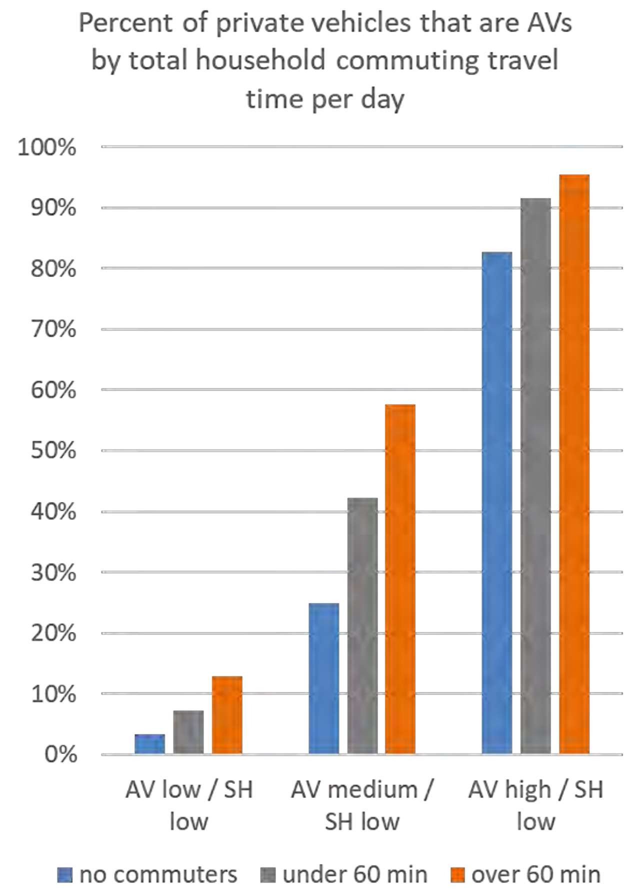


Private Vehicle Ownership
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Base
LL
ML
HL
LM
LH
AV
Conv

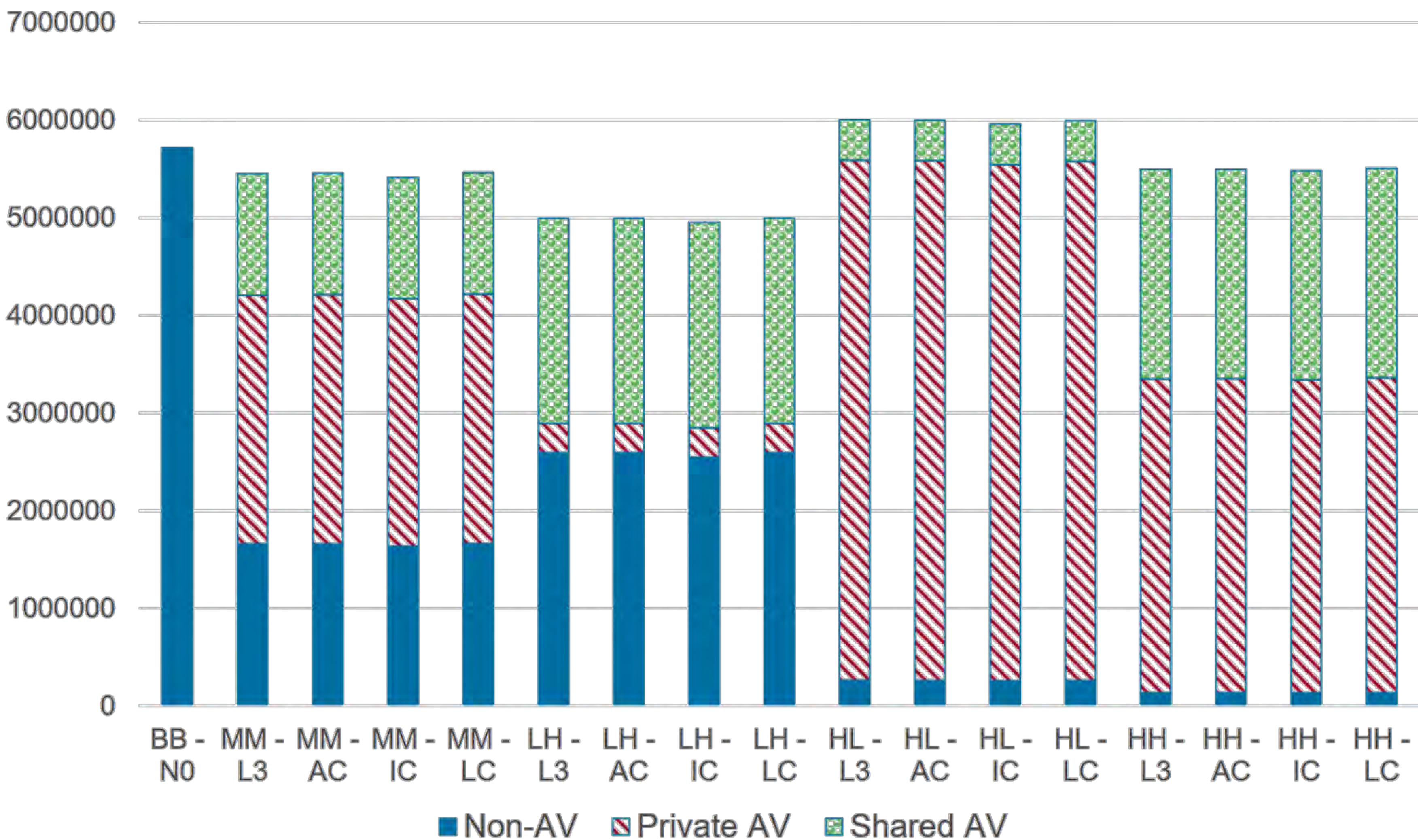
Vehicle Ownership – Breakout



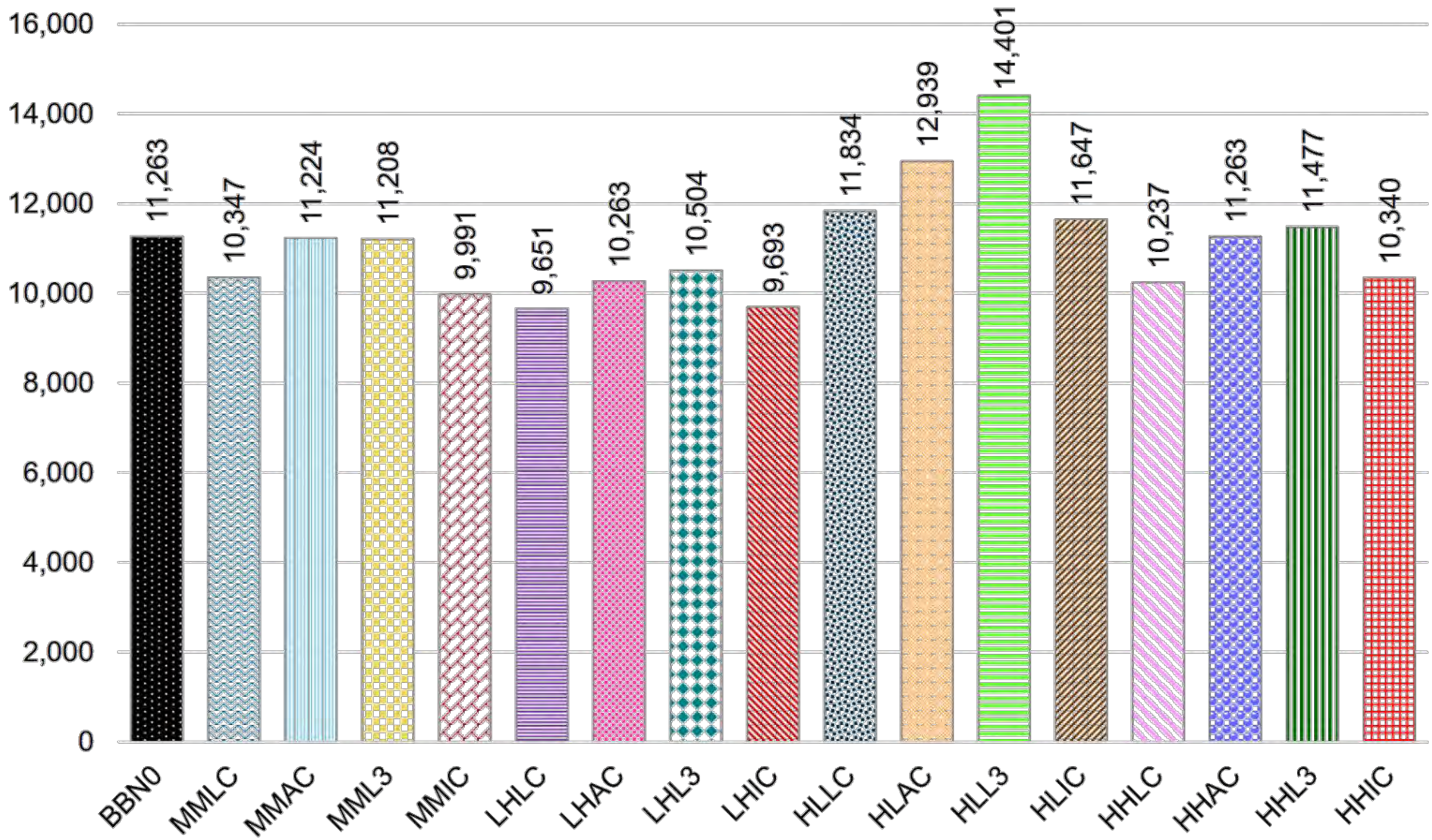




AM VMT, by Vehicle Type and Scenario



DTA Vehicle-Hours of Delay, by Scenario

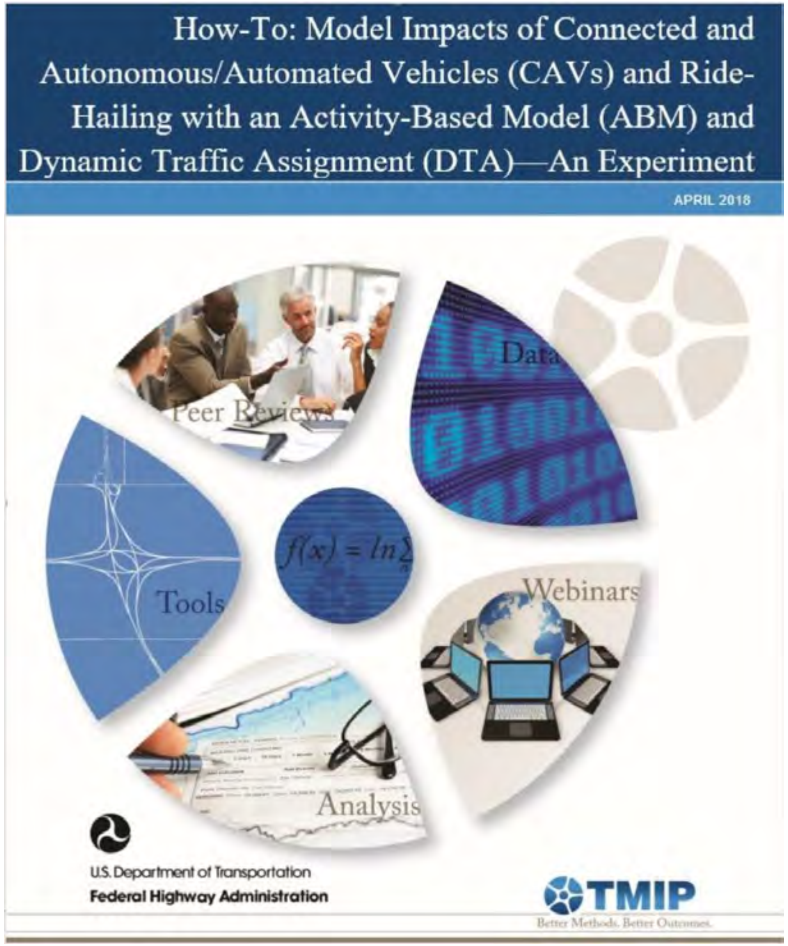


Regression Model on ABM Output: Total VMT (millions), by Scenario / Time Period / Vehicle Type

Vehicle Type	Non-AV	Non-AV	Private AV	Private AV	Shared AV	Shared AV	All types	All types
Variables	**Coeff.**	**T-stat**	**Coeff.**	**T-stat**	**Coeff.**	**T-stat**	**Coeff.**	**T-stat**
Constant	0.262	11.1	0.443	10.6	0.226	12.9	0.931	117.6
Demand - High Private, Low Shared	-0.174	-9.8	0.346	11.0	-0.103	-7.8	0.068	11.4
Demand - Low Private, High Shared	0.116	6.5	-0.281	-8.9	0.108	8.1	-0.057	-9.6
Demand - High Private, High Shared	-0.190	-10.6	0.083	2.6	0.113	8.5	0.006	1.1
Supply - Network scenario AC	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0
Supply - Network scenario IC	-0.002	-0.1	-0.002	-0.1	0.000	0.0	-0.004	-0.7
Supply - Network scenario LC	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.1
Arrive Period - 5:00 to 5:29	-0.182	-7.2	-0.434	-9.7	-0.237	-12.7	-0.853	-100.7
Arrive Period - 5:30 to 5:59	-0.177	-7.0	-0.422	-9.5	-0.231	-12.3	-0.830	-98.1
Arrive Period - 6:00 to 6:29	-0.051	-2.0	-0.109	-2.5	-0.075	-4.0	-0.235	-27.8
Arrive Period - 6:30 to 6:59	-0.057	-2.3	-0.125	-2.8	-0.081	-4.3	-0.263	-31.1
Arrive Period - 7:00 to 7:29	0.035	1.4	0.107	2.4	0.051	2.7	0.192	22.7
Arrive Period - 7:30 to 7:59	0.008	0.3	0.042	0.9	0.026	1.4	0.076	9.0
Arrive Period - 8:30 to 8:59	-0.017	-0.7	-0.048	-1.1	-0.018	-1.0	-0.083	-9.8

EMA Summary

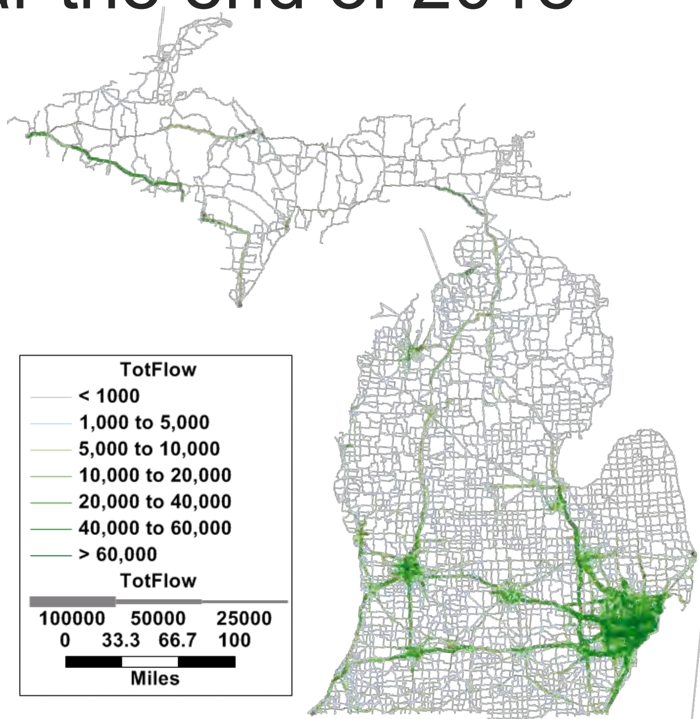
- Assumptions
  - Level 3
  - No ZOVs
  - AM peak only
  - Uncertainty in levels of private and shared CAVs, dedicated lanes
- Results
  - Delay varied from -14% to +28%
  - Private CAVs increased VMT
  - Shared CAVs decreased VMT
  - Specific technology assumptions had different delay implications
  - Dedicated left lane almost as good as dedicating all freeway lanes



A Trip-Based Framework for CAVs

The New Michigan Statewide Model

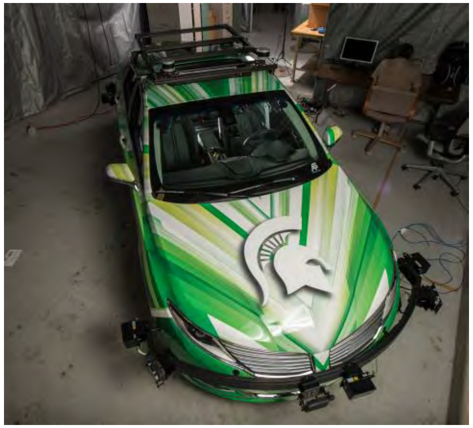
- One of the longest traditions of statewide modeling in the country since early 1970's
- Last major update was mid 1990's
- New model complete near the end of 2018
  - Data-driven approach using AirSage & ATRI
  - Advanced trip-based passenger modeling
    - Linkage of HB & NHB, LD and Visitor trips
  - Commodity-flow based freight modeling
  - Summer model



CAVs in Michigan

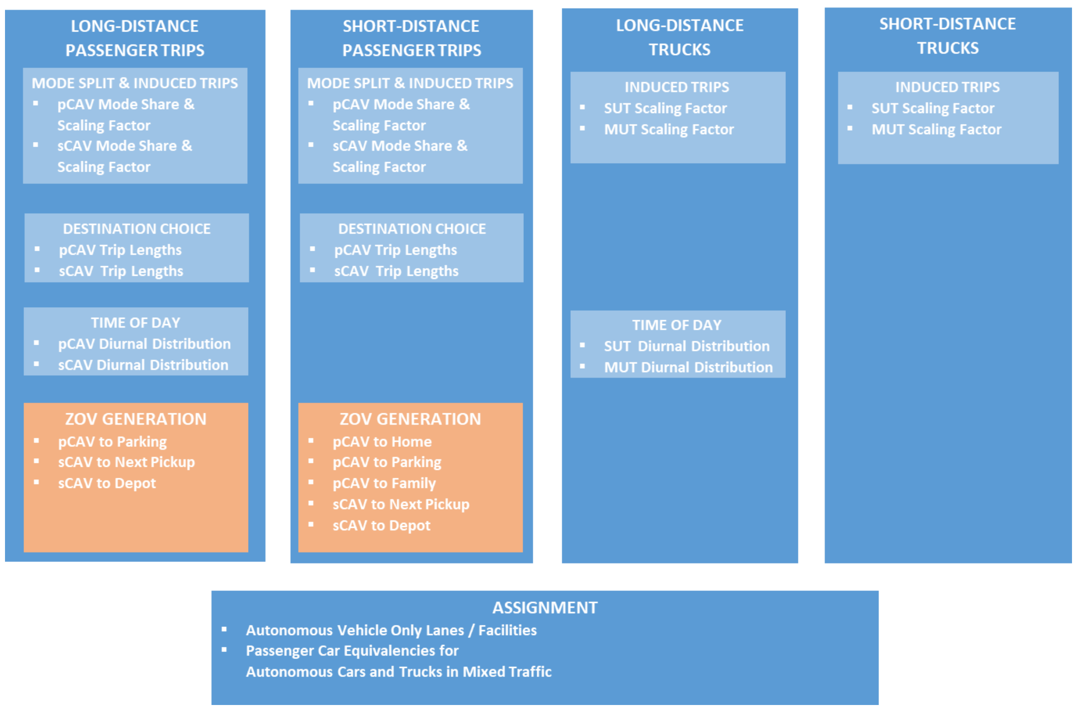
- Home of the Auto Industry
  - All auto-makers actively investing in CAV technology
- Public-Private Partnerships
  - Research rapidly moving into reality
    - U of M has been using autonomous shuttles for almost a year

ANN ARBOR CONNECTED VEHICLE TEST ENVIRONMENT



CAVs in Trip-Based Models

- Lots of off-model / manual analysis
- Michigan, Illinois statewide models
- New factors / market segments + ZOV step



CAVs in Trip-Based MPO Models

- Lots of off-model / manual analysis
- Adapted Michigan framework
- Charleston, Charlottesville, & Ann Arbor MPOs

RESIDENT INTERNAL PASSENGER TRIPS

AUTO OWNERSHIP
- Overall Ownership Level
- Split of Vehicles between CAV vs. Conventional

INDUCED TRIPS
- Adjust Trip Rates by Seniors, Children, Autos

DESTINATION CHOICE
- Adjust Trip Lengths by CAV ownership

MODE CHOICE
- Add MaaS modes
- Add CAV / Conv. Submodes

ZOV GENERATION
- HH CAV to Family
- HH CAV to Home
- HH CAV to Free Parking
- HH CAV to Circulate
- MaaS CAV to Next Pickup
- MaaS CAV to Depot

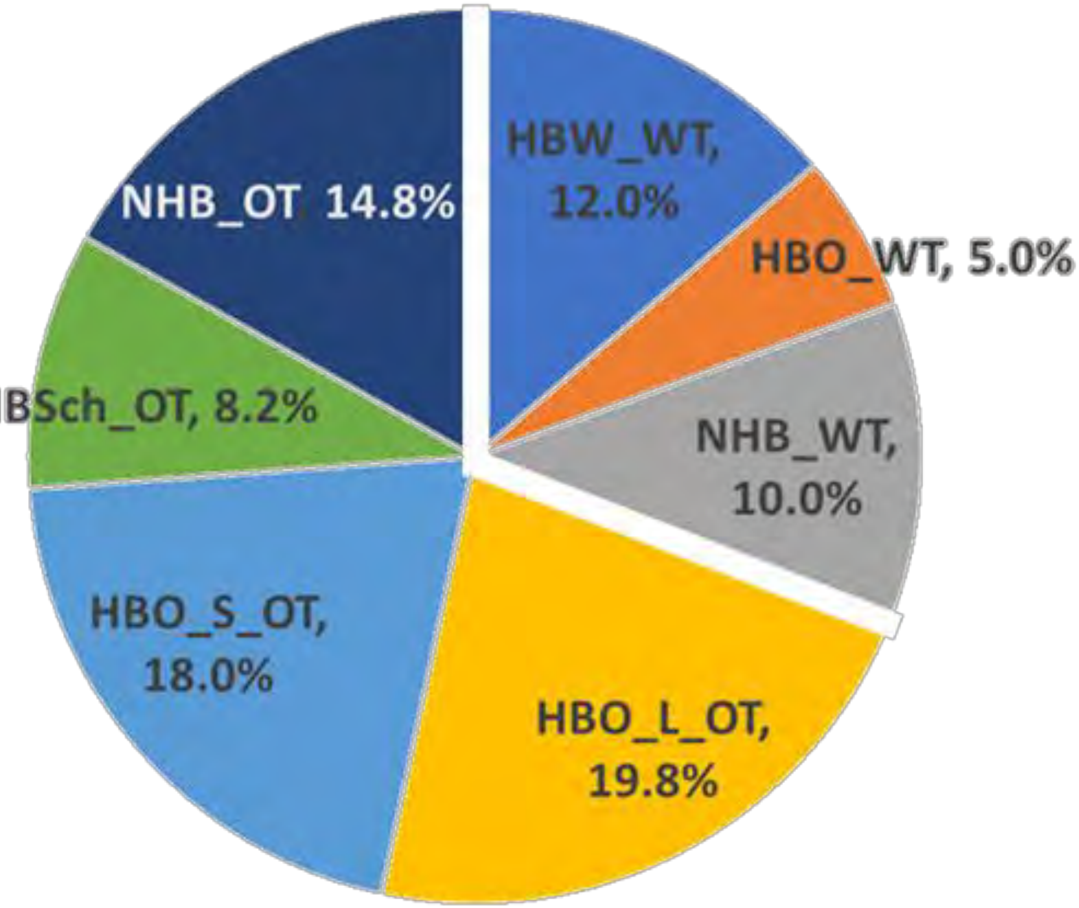
EXTERNAL AND TRUCK TRIPS

INDUCED TRIPS
- EE & EI/IE Scaling Factors
- SUT Scaling Factor
- MUT Scaling Factor

TIME OF DAY
- Ext Diurnal Distributions
- Trk Diurnal Distributions

ASSIGNMENT
- Autonomous Vehicle Only Lanes / Facilities
- Passenger Car Equivalencies for Autonomous Cars and Trucks in Mixed Traffic

Model Segmentation



- Vehicle Ownership
  - No vehicles
  - Vehicles < Adults
    - Without CAV
    - With CAV
  - Vehicles ≥ Adults
    - Without CAV
    - With CAV
- Non-Work Activities segmented by DURATION
  - Less than 30 min (won't send vehicle home)
  - Greater than 30 min (might send vehicle home)

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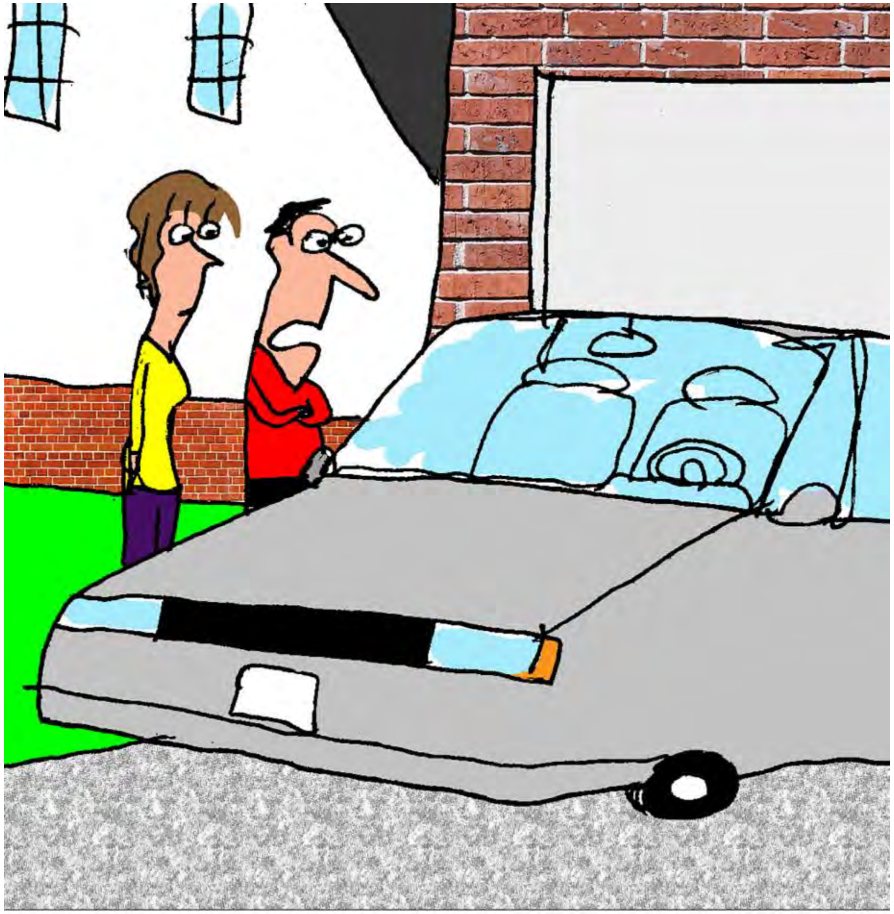
Auto Ownership

- Subdivide HH autos into conventional and CAV by income
- Decrease overall ownership



"Maybe I can buy a self driving car, and hire it out to Uber to make the payments."

CartoonStock.com

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Trip Generation

Source: Jalopnik.com

- Scale up trips to represent induced demand
- Largest increases to households with:
  - Disabled
  - Seniors
  - Children
- More long distance / external trips from reduced lodging cost?
- [Also, careful of trip rates by vehicle ownership]

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Trip Distribution

- Passengers may be willing to travel farther since time in CAVs can be used positively for working, relaxing, sleeping, etc.
- User can factor down traveler sensitivity to travel time / impedance

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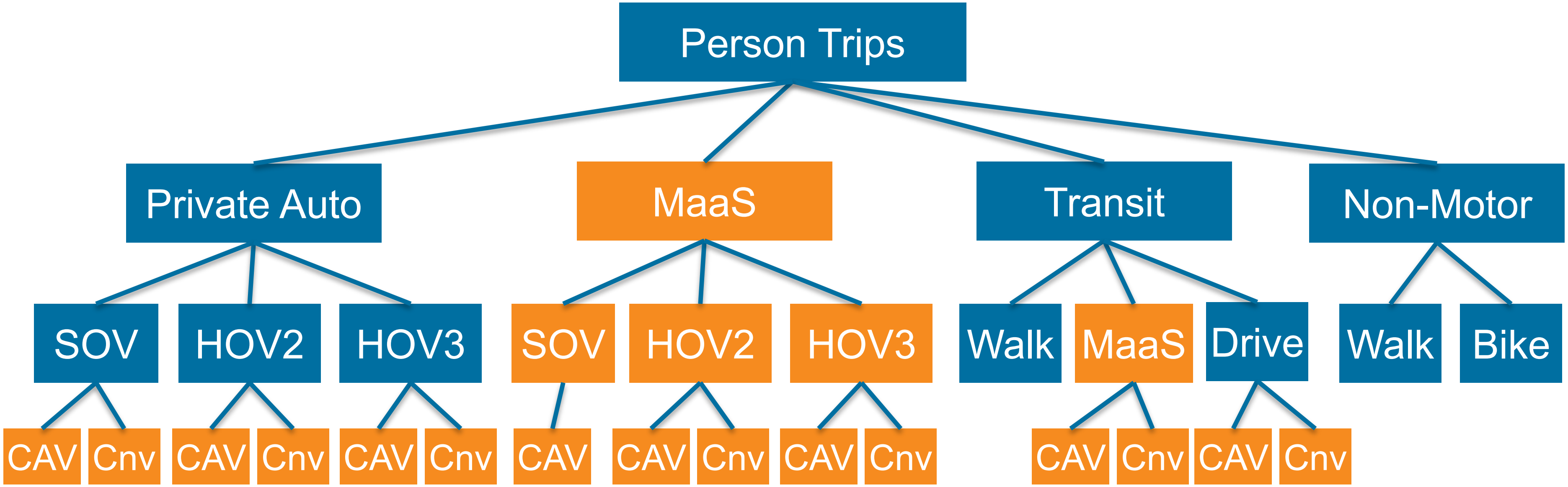
Mode Choice

- Add Taxi / TNC mode
- Decrease cost &
- Vary occupancy

Source: Futurism.com

Mode Choice

- Add MaaS mode
- Add CAV / Conventional Submodes
- User specified shares for all modes or only new



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Long-Distance & Trucks

Source: theautofuture.com

- Long distance travelers may use sleeping hours to travel

- There may be more long distance (external) trips as the cost of travel is reduced

- Trucks / long distance travelers may shift to nighttime hours to avoid congestion

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Deadheading / ZOVs

Source: driverlesstransportation.com

- Types of ZOV trips
  - Private CAVs
    - for car sharing among household members (1)
    - to avoid paid parking
      - by parking at home (2)
      - by parking elsewhere (3)
      - by circulating instead of parking (4)
  - Shared CAVs
    - for passenger pick-up/drop-off (5)
    - to/from depots (6) (for re-charging / demand response)

Private CAV ZOV Modeling Methods

1. for car sharing among household members
   – invert asserted percentage of Os & Ds, gravity model
2. to avoid paid parking by parking at home
   – invert asserted percentage of HB trip ODs for pay TAZs
3. to avoid paid parking by parking elsewhere
   – create trips between pay TAZ & nearest non-pay TAZs as a function of long Ds at pay TAZ
4. to avoid paid parking by circulating instead of parking
   – after assignment, factor up volumes on non-freeway links within buffer of pay TAZ based on short stops

Shared CAV ZOV Modeling Methods

5. for passenger pick-up/drop-off
   – invert all passenger Os & Ds; gravity model
6. to/from depots (for re-charging / demand response)
   – assert depot TAZs with capacities; generate trips by min(difference in demand between periods, charging requirement assumption); gravity between shared CAV Os & Ds and depot TAZ

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Assignment

- Separate autonomous and conventional vehicle classes
- User option to have dedicated CAV-only facilities/lanes and assert high capacities and higher speeds
- User option to assert different capacity consumption in mixed traffic (through PCE factor)

Scenario Planning Example

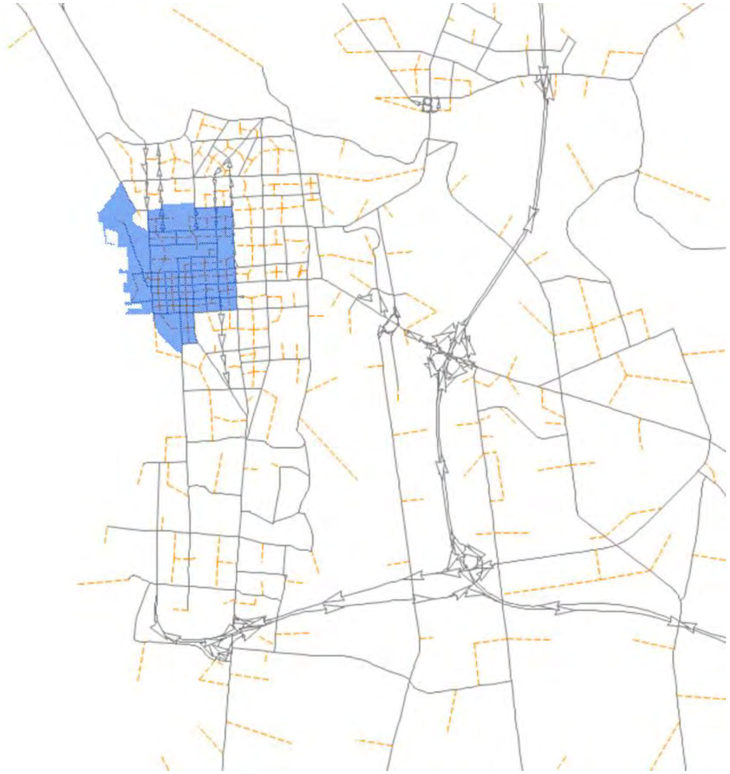
Burlington, VT Scenario Planning

- Intended to start a conversation about future transportation and traffic implications of the impending CAV future for LRTP
- Not used in selecting projects
- Two scenarios
  - 80% CAV, 50% shared, base occupancy
  - 100% CAV, 65% shared, higher occupancy

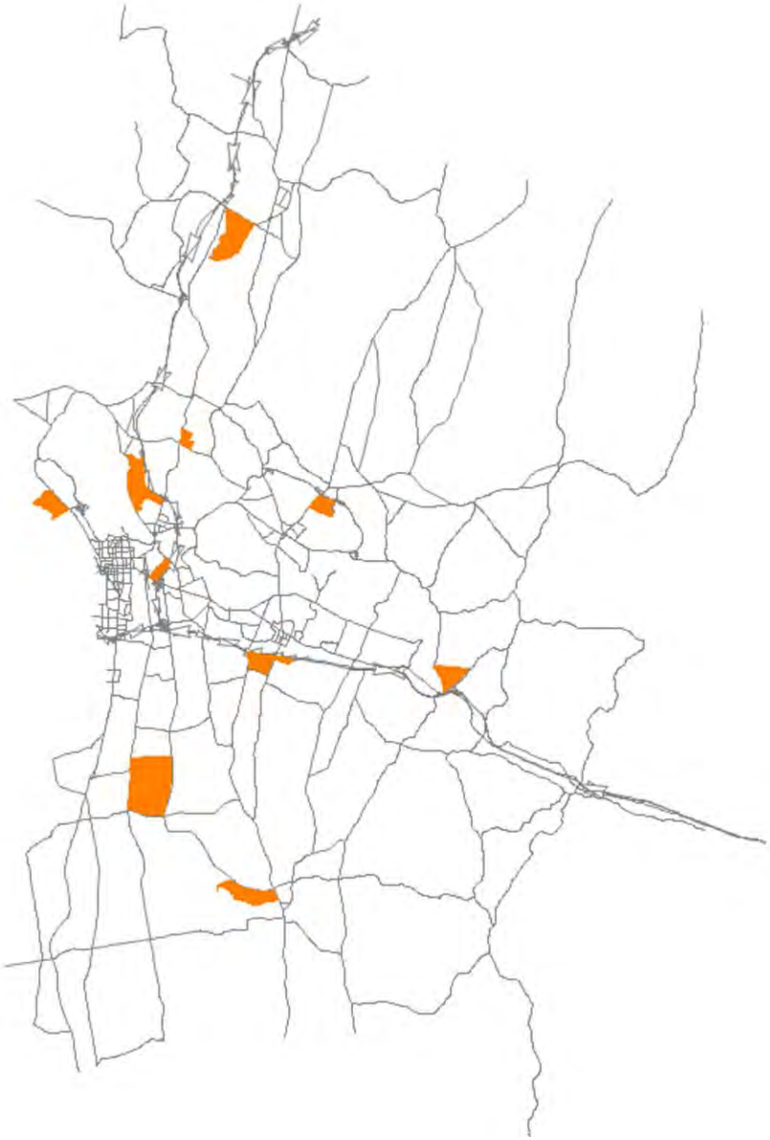
Burlington, VT Scenario Assumptions

- 5% more HBO for induced person trips
- No temporal or destination choice changes
- All ZOV types except intra-household sharing
- Generous increased capacity assumptions
  - Doubling of freeway capacity for 80% scenario
  - Tripling of freeway and 50% increase of arterial capacity for 100% scenario

Burlington, VT
Scenario Assumptions



Pay Parking TAZ



Depot TAZ

Burlington, VT Scenario Results

	Baseline	CAV (PCE=1.08) 80% CAV	CAV (PCE=1) 100% CAV
Total VMT	5,407,153	7,257,230	5,778,606
Total VHT	156,847	230,545	163,905
VMT/Person	29.5	39.6	31.5
VHT/Person	0.9	1.3	0.9
VMT/Person Trip	5.96	6.02	4.53
VHT/Person Trip	0.24	0.34	0.3
Total Delay (minutes)	1,686,780	3,338,833	1,441,049
Delay/Person	9.21	18.23	7.87
Delay/Vehicle Trip	2.53	3.46	1.79
Average Length of Trip (miles)	8.65	7.52	7.17
Average Length of Trip (minutes)	16.02	14.33	12.20
All Vehicle Trips	666,388	965,533	805,927
ZOV Trips	-	295,009	269,646
% ZOV	-	31%	33%

Conclusions

Parting Thoughts

- Models can be enhanced to capture almost (but not) all dimensions of uncertainty about CAVs
  - Add adjustments to all steps
  - Add taxi/TNC mode
  - Add special ZOV components
- They can NOT tell us what will happen
- They CAN help us understand
  - the range of possible futures
  - the relative importance of different factors
  - the robustness of policies / investments

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