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

Region-wide, Six-county coverage
Jacksonville Model Overview

Parcel-level activity location
Jacksonville Model Overview

Major and local streets and centroid connectors
Jacksonville Model Overview

Intersection geometry and signal timings
Validation of Dynamic Skims

Dynamic versus static

Outlier review

2551-919
650-1060
1084-2286
858-1280
2226-382
1091-1030
1597-183
10-541
896-759
410-2577
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

<table>
<thead>
<tr>
<th>SCENARIO</th>
<th>PRIVATE AV ADOPTION</th>
<th>SHARED AV ADOPTION</th>
<th>RESERVED AV CAPACITY</th>
<th>AUTOMATION LEVEL</th>
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<td>Interstate left lanes</td>
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<td>Level 3 + ACC</td>
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- **SAE 3 +/- CACC**
- **Adoption**
  - High
  - Medium
  - Low
  - None
- **Split of Private vs. Shared**
- **CAV only lanes / freeways**
Scenarios

Private Vehicle Ownership

Shared Ride Mode Share

Base  LL  ML  HL  LM  LH

AV  Conv
Vehicle Ownership – Breakout

Percent of private vehicles that are AVs by age category of head of household

Percent of private vehicles that are AVs by household income category

Percent of private vehicles that are AVs by total household commuting travel time per day

- AV low / SH low
- AV medium / SH low
- AV high / SH low

- head under 35
- head 35-64
- head 65 plus

- under $50k
- $50-100k
- over $100k

- no commuters
- under 60 min
- over 60 min
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

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Non-AV Coeff.</th>
<th>Non-AV T-stat</th>
<th>Private AV Coeff.</th>
<th>Private AV T-stat</th>
<th>Shared AV Coeff.</th>
<th>Shared AV T-stat</th>
<th>All types Coeff.</th>
<th>All types T-stat</th>
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<td>2.6</td>
<td>0.113</td>
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<td>0.006</td>
<td>1.1</td>
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</tbody>
</table>
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
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
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)
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/E 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
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."
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ASSIGNMENT

- Autonomous Vehicle Only Lanes / Facilities
- Passenger Car Equivalent for Autonomous Cars and Trucks in Mixed Traffic
Trip Generation

- 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]

Source: Jalopnik.com
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ASSIGNMENT

- Autonomous Vehicle Only Lanes / Facilities
- Passenger Car Equivalencies for Autonomous Cars and Trucks in Mixed Traffic
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
<table>
<thead>
<tr>
<th>RESIDENT INTERNAL PASSENGER TRIPS</th>
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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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- AUTO OWNERSHIP
  - Overall Ownership Level
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ASSIGNMENT
- Autonomous Vehicle Only Lanes / Facilities
- Passenger Car Equivalencies for Autonomous Cars and Trucks in Mixed Traffic
Long-Distance & Trucks

• 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

• 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)

Source: driverlesstransportation.com
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(\text{difference in demand between periods, charging requirement assumption}); gravity
     between shared CAV Os & Ds and depot TAZ
RESIDENT INTERNAL PASSENGER TRIPS

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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

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<th>CAV (PCE=1.08)</th>
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<tr>
<td>Total VMT</td>
<td>5,407,153</td>
<td>7,257,230</td>
</tr>
<tr>
<td>Total VHT</td>
<td>156,847</td>
<td>230,545</td>
</tr>
<tr>
<td>VMT/Person</td>
<td>29.5</td>
<td>39.6</td>
</tr>
<tr>
<td>VHT/Person</td>
<td>0.9</td>
<td>1.3</td>
</tr>
<tr>
<td>VMT/Person Trip</td>
<td>5.96</td>
<td>6.02</td>
</tr>
<tr>
<td>VHT/Person Trip</td>
<td>0.24</td>
<td>0.34</td>
</tr>
<tr>
<td>Total Delay (minutes)</td>
<td>1,686,780</td>
<td>3,338,833</td>
</tr>
<tr>
<td>Delay/Person</td>
<td>9.21</td>
<td>18.23</td>
</tr>
<tr>
<td>Delay/Vehicle Trip</td>
<td>2.53</td>
<td>3.46</td>
</tr>
<tr>
<td>Average Length of Trip (miles)</td>
<td>8.65</td>
<td>7.52</td>
</tr>
<tr>
<td>Average Length of Trip (minutes)</td>
<td>16.02</td>
<td>14.33</td>
</tr>
<tr>
<td>All Vehicle Trips</td>
<td>666,388</td>
<td>965,533</td>
</tr>
<tr>
<td>ZOV Trips</td>
<td>-</td>
<td>295,009</td>
</tr>
<tr>
<td>% ZOV</td>
<td>-</td>
<td>31%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>33%</td>
</tr>
</tbody>
</table>
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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