ESTIMATING POTENTIAL ENERGY AND MOBILITY IMPACTS OF CAVS IN THE U.S.

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AUTOMATED VEHICLES SYMPOSIUM 2018 — Driven by: AUVSI & TRB

PROJECT OVERVIEW

Objective: Estimate potential changes in travel demand and energy consumption due to deployment of connected and automated vehicles (CAVs) at a national level

- Develop CAV deployment scenarios
  - Highly automated vehicles: privately-owned, and shared
  - Connected, partially automated vehicles, with cooperative adaptive cruise control (CACC) and coordinated flow through intersections
- Use **economic/market model** to estimate changes in travel and energy use (given AV adoption levels) at a national scale
- Develop **consumer adoption model** for highly automated vehicles (national scale, with segmentation)
- Develop **aggregation/expansion methods** to extrapolate detailed, regional simulation results to the national level

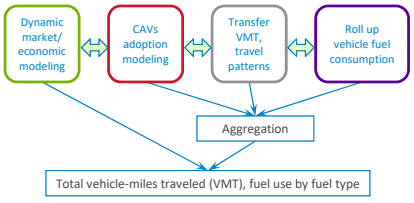
MOTIVATION

- CAVs **may disrupt travel patterns, vehicle use and ownership, and even vehicle design** with large changes in energy consumption
- Economic theory and market models can provide credible estimates of possible future changes in **travel demand and energy use** (Leiby & Rubin, 2018, Lin & Xie, 2018)
- Recent and ongoing analysis of CAVs under the U.S. Department of Energy Vehicle Technologies Office-funded SMART Mobility CAVs Pillar are providing estimated energy impacts at the local and regional levels (Auld et al., 2017)
  - Methods are being developed to **expand** these results (and others as available) **to the national level**

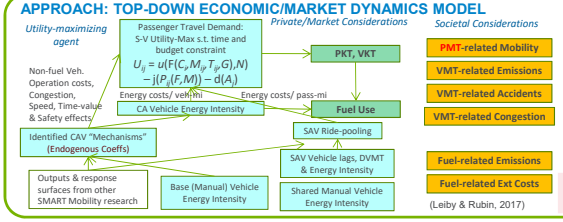
GENERAL APPROACH

Estimate potential changes in travel behavior and energy consumption due to deployment of CAVs using *top-down* and *bottom-up* approaches

- Economic/Market Dynamics ("Top Down") model
- Model adoption of CAVs and shared vehicles by consumer segment
- Develop methods to expand regional simulation results using transferability modeling and to aggregate results of detailed, regional case studies to the national level ("Bottom-up")

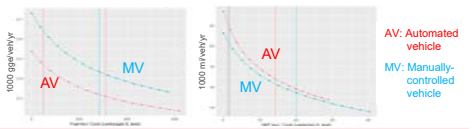


APPROACH: TOP-DOWN ECONOMIC/MARKET DYNAMICS MODEL



INITIAL RESULTS:

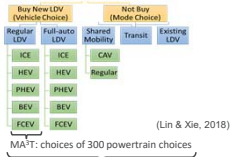
- Modeled response of travel demand (VMT) and fuel use under different cost assumptions



- For both manual and automated vehicles, the fuel use and annual distance driven decreases with increasing cost, but decline more rapidly with VMT-related cost/disincentive
- Estimates of travel demand are sensitive to assumed VOTT and other costs

APPROACH: MODELING ADOPTION OF CAVS AND SHARED MOBILITY

- MA^{3}T-Mobilty Choice (extension of ORNL MA^{3}T model)
- Jointly model choices:
  - Automation/no automation
  - Privately-owned/shared
  - Powertrain type
- Quantify utility to consumers within different market segments and resulting impacts on ownership and operation decisions
- Taking into account consumer segments
  - Household income, demographics
  - Travel behavior
  - Life cycle
  - Urban/rural, etc.

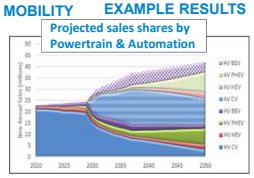


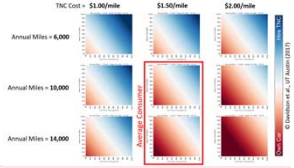
(Lin & Xie, 2018)

MA^{3}T: choices of 300 powertrain choices

MA^{3}T-MC: competition and synergy among powertrain, automation, and sharing

EXAMPLE RESULTS





- MA^{3}T-MC model provides credible estimates of adoption of CAVs, alt-fuel powertrains, and shared mobility options for scenario development

APPROACH: TRANSFERRING REGIONAL SIMULATION RESULTS TO NATIONAL LEVEL

Activity-based model (POLARIS) of Chicago metro region for baseline and CACC scenarios (Auld et al., 2017)

Disaggregated simulation results
- Socio-demographics
- Land use, built environment
- Activities and travel (trips, VMT)

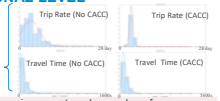
Cluster regional population

Transfer to national population

National-level travel patterns
- Trip rate (trips per day)
- Travel time per day
- Travel demand (VMT)

Two scenarios:
- Baseline (No CACC)
- CACC all vehicles)

Example results for Cluster 3:

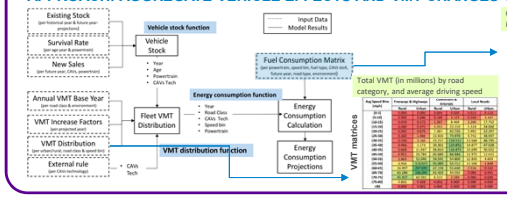


- In CACC scenario, many travelers make a few more trips but travel for significantly longer times
- National-level VMT will be used to estimate fuel use

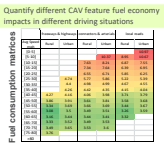
Cluster ID	Average Daily Trip Rate	Average Daily Trip Rate	Average Travel Time (min/day)	Average Travel Time (min/day)
	No CACC	CACC	No CACC	CACC
1	4.14	3.97	78.6	115.0
2	3.85	4.07	73.3	88.7
3	3.65	3.89	75.5	103.2
4	8.16	8.96	148.1	163.4
...	...	...	...	...
11	3.83	3.85	71.4	80.1

(Shabanpour et al., 2018)

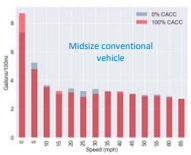
APPROACH: AGGREGATE VEHICLE EFFECTS AND VMT CHANGES TO NATIONAL LEVEL



Quantify different CAV feature fuel economy impacts in different driving situations



EXAMPLE RESULTS



Fuel consumption estimated for vehicles on multilane freeway with and without CACC (microsimulations by Liu et al. 2018)

- Fuel consumption per mile decreases with CACC at most speeds
- Most freeway VMT and hence CACC fuel savings are seen at relatively high speeds
- Distributions of VMT and fuel consumption per mile change with CACC

- National-level aggregation framework will be used to combine vehicle-level fuel consumption and VMT impacts of CACC and other CAVs technologies for scenarios of interest

SCENARIOS TO BE ANALYZED (OR UNDER CONSIDERATION)

- Base case: similar to Energy Information Administration Annual Energy Outlook Reference case
- Personal travel with different levels of adoption of cooperative adaptive cruise control (CACC) and intersection control
- Personal travel with highly automated, privately-owned or shared vehicles (taxis) with different operational design domain (allowable operating conditions)
- Different levels of traffic control

SUMMARY/CONCLUSIONS

- An analytical model developed to describe the influence of CAVs adoption on Mobility (VMT) and fuel use under a wide range of assumptions about how vehicle automation will change:
  - Value of travel time
  - Vehicle fuel economy and emissions
  - Crash frequency
  - Congestion
- The model accounts for travelers' budget and time constraints and effects of taxes
- Perceived costs/utilities of travel can significantly influence travel demand (VMT) and resulting fuel use
  - Estimates of travel demand are sensitive to assumed VOTT and other costs
- Costs and values of CAV technologies to consumers are used in the MA^{3}T-MC model to assess potential adoption by different consumer segments
  - Adoption of CAVs, alt-fuel powertrains, and shared mobility options is estimated jointly for multiple consumer segments
- Results of regional (metropolitan-area) transportation system simulations with CAVs are being transferred to the national level
  - Details from activity-based model are combined with national-level data
- An analytical framework to assess energy and mobility impacts of CAV nationally was demonstrated
  - Considers technology progress in non-CAVs and CAVs fleet
  - Captures potential spatial and temporal energy impacts of CAVs on vehicle efficiency and vehicle use (VMT)
- These will enable analysis of scenarios to relate energy outcomes to assumed future conditions and technology drivers

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