UCR | College of Engineering- Center for Environmental Research & Technology

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Evaluating Energy Efficiency Opportunities from Connected and Automated Vehicle (CAV) Deployments coupled with Shared Mobility in California

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Partner: National Renewable Energy Laboratory

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DOE Vehicle Technologies Office
2018 Annual Merit Review and Peer Evaluation Meeting
Project ID # DE-EE0008212
Project Number: EEMS032

Overview

Timeline

- Project start date: 10/01/2017
- Project end date: 09/30/2019
- Percent complete: 30%

Budget

- Total project funding
  - DOE share: $1,094,578
  - Contractor share: $122,882
- Funding for FY 2017: N/A
- Funding for FY 2018: $694,879

Barriers

- Measuring the transportation system-wide energy impacts of CAVs
- Determining the value and productivity derived from new mobility technologies
- Sourcing empirical real-world data applicable to new mobility technologies

Partners

- National Renewable Energy Laboratory
  - Jeff Gonder

Objectives

- **Project Objectives:**
  - Evaluate energy efficiency opportunities from large-scale (e.g., regional or statewide) deployments of Connected and Automated Vehicles (CAVs) coupled with Shared Mobility
  - Integrate existing and ongoing research on Shared Electric Connected and Automated (SECA) Transportation
  - Investigate under a variety of roadway infrastructure, traffic congestion levels and market penetration rate
  - Major focus on California
- **Objectives over the past year (Oct 2017–Mar 2018):**
  - Collection and processing of real world and simulation CAV data
  - Data collection from real world shared mobility applications
  - Development of model framework

Relevance

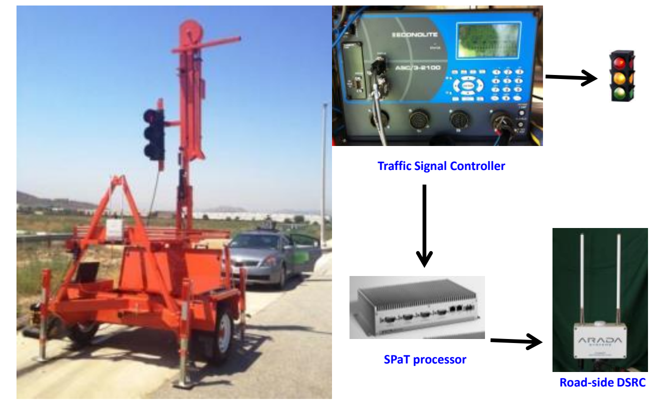
- **This project addresses multiple VT Office/EEMS barriers by**
  - Quantifying the energy impact of disruptive transportation changes
  - Identifying real-world data sources for SECA applications
  - Investigating travel cost and travel behavior changes due to new mobility technologies
- **Impact of the project:**
  - Close the knowledge gap on understanding potential system impacts of large-scale CAV technology deployments in the shared mobility era
  - Reduce uncertainty in estimating energy saving opportunities from new mobility technologies
  - Support policymakers in steering CAV and shared mobility development in an energy-favorable direction

Milestones

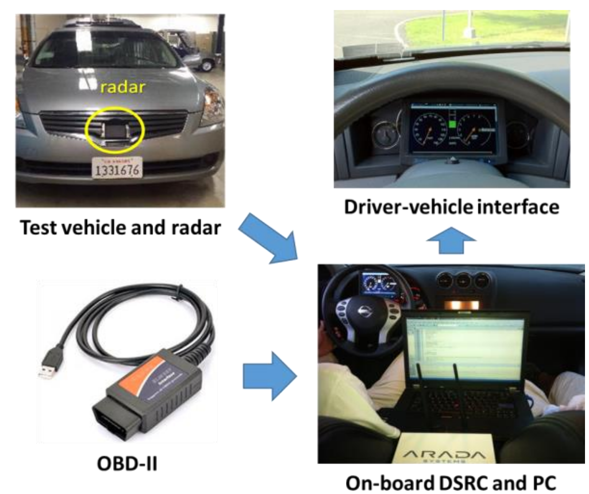
Milestone	Description	(Planned) Completion Date	Status
TaFY 2018			
Data source identification and experiment setup complete	Data source identification and experiment setup complete	12/31/2017	Complete
Collection and processing of LDV data complete	Complete collection and processing of LDV-No Automation real world data	3/31/2018	Complete
Collection and processing of HDV data complete	Complete collection and processing of HDV-No Automation data and LDV simulation data	6/30/2018	Ongoing
Assessment of Data Collection Complete	Determine if a sufficient amount of data have been collected to support model implementation	9/30/2018	Ongoing
FY 2019			
Energy intensity (EI) model implementation	Complete implementation of models for estimating impacts on energy intensity by CAV technologies	12/31/2018	Ongoing
Completion of Model Implementation/Validation	Determine if all models have received sufficient validation for supporting statewide energy inventory efforts	3/31/2019	Not started
Framework Development	Complete the development of statewide energy inventory framework	5/30/2019	Ongoing
Impacts Evaluation	Complete the evaluation of CAV-induced energy impacts in California	7/30/2019	Not started

Approach – Data Collection and Processing

- Data from real-world CAV implementations
  - Field experiments and demonstrations
  - Early real-world deployments
- Data from micro-simulation
  - Multiple CAV applications
- Shared mobility data
  - Ride-hailing, ride-sharing and car sharing data from existing deployments
- Literature review
  - e.g. previous studies from SMART Mobility Initiative
- Data processing
  - Data cleaning and normalization
  - Categorized by traffic demand, penetration rate, effective area, etc.



Road-side signal control and communication system



Onboard CV based speed advisory system

Approach – Modeling and Analysis

- **Meso/Micro-scopic:**
  - Identify future transportation system scenarios in term of different SECA penetration and development levels
  - Design a platform to accommodate all major SECA applications
  - Estimate the impact of SECA on energy intensity and modal activity
  - Evaluate the operation performance for each scenario and convert that to travel cost factors for travelers
- **Macroscopic:**
  - Develop travel behavior model – how travelers (grouped by demographics and trip purposes) value different travel cost factors and choose the mode
  - Calculate the mode specific OD trip based on Southern California Association of Governments (SCAG) model
  - Impact analysis on mobility and energy-efficiency
  - Potential policies (e.g. occupancy based pricing) to mitigate the negative impacts

Accomplishments – Initial CAVs Data Collection

Early Field Deployments

- Safety Pilot Model Deployment (SPMD)
  - Ann Arbor, MI: 3000 vehicles with CV safety technologies
- Multi-Modal Intelligent Traffic Signal Systems (MMITSS)
  - Anthem, AZ: Vehicle trajectories and BSM files for safety applications
  - Redwood Road, UT: Transit Signal Priority to improve schedule reliability
  - Palo Alto, CA: Connected Vehicle Pilot Deployment
- Connected Vehicle Pilot Deployment Program
  - Wyoming, New York City, and Tampa
- Ongoing CAV deployment for heavy-duty vehicles
  - Los Angeles County, CA: Connected heavy-duty truck location and Electronic Control Unit (ECU) data from Eco-FRATIS and Volvo projects
  - Riverside, CA: Connected eco-bus data along the Riverside Innovative Corridor from ARPA-E NEXTCAR project

Accomplishments – Initial CAVs Data Collection

Example field experiments and demonstrations

Technology	Location	Communic ation	Energy Savings	Reference
EAD with Fixed Signals	Richmond, CA	4G/LTE	14%	Xia et al., 2012
	Riverside, CA	DSRC	11%-28%	Xia, 2014
	McLean, VA	DSRC	2.5%-18%	Xia, 2014
EAD with Actuated Signals	Riverside, CA	DSRC	5-25%	Hao et al., 2015
	Palo Alto, CA	DSRC	7%	Hao et al., 2018
EAD with Automation	McLean, VA	DSRC	10-20%	Altan et al., 2017

Micro-simulation

- Eco-Approach and Departure (EAD) — 10 – 25% energy saving

  Varying Performance in terms of penetration rate, traffic demand, facility type, etc.
- Eco-Cooperative Adaptive Cruise Control — 19% energy saving
- Eco-speed harmonization — 4.5% energy saving
- Eco-signal priority — 4% for freight; ~6% for all
- Lane Speed Monitoring (LSM), Emergency Electronic Brake Light (EEBL) and High Speed Differential Warning (HSDW) — Mobility and safety benefits

Accomplishments – Initial Shared Mobility Data Collection

Example shared mobility datasets

Name	Type	Location	Description
UCR IntelliShare	Car-sharing	Riverside, CA	A shared electric vehicles program
New York City Taxi Data	TNC included	New York City	Pick up/ drop off location and time
TNCs TODAY	TNC	San Francisco, CA	6-weeks data aggregated by time/zones
RideAustin	Ride-sharing	Austin, TX	Comprehensive ridership data
GAIA initiative	TNC	Chengdu, China	Trip information and vehicle trajectories

TNC datasets can show

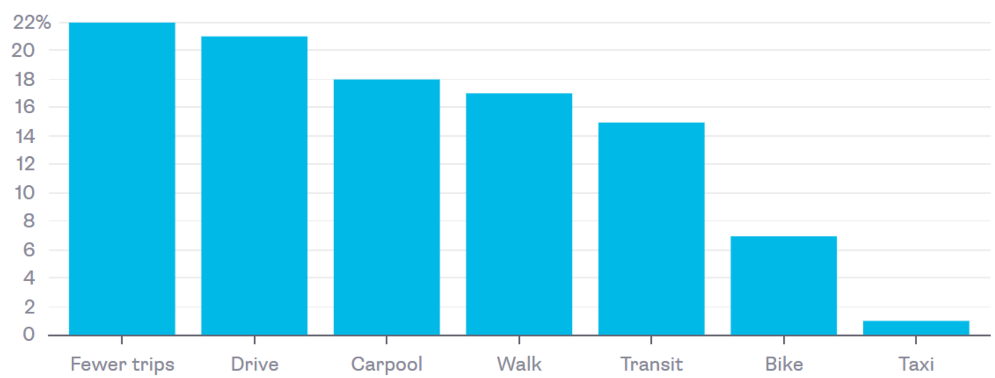
- TNC trip distribution in term of location and time
- The % of zero passenger trips
- How zero passenger vehicles relocate

TNC datasets cannot tell

- Ride-pooling or not (occupancy)
- Mode shifting due to TNC travel (need to integrate survey response data)

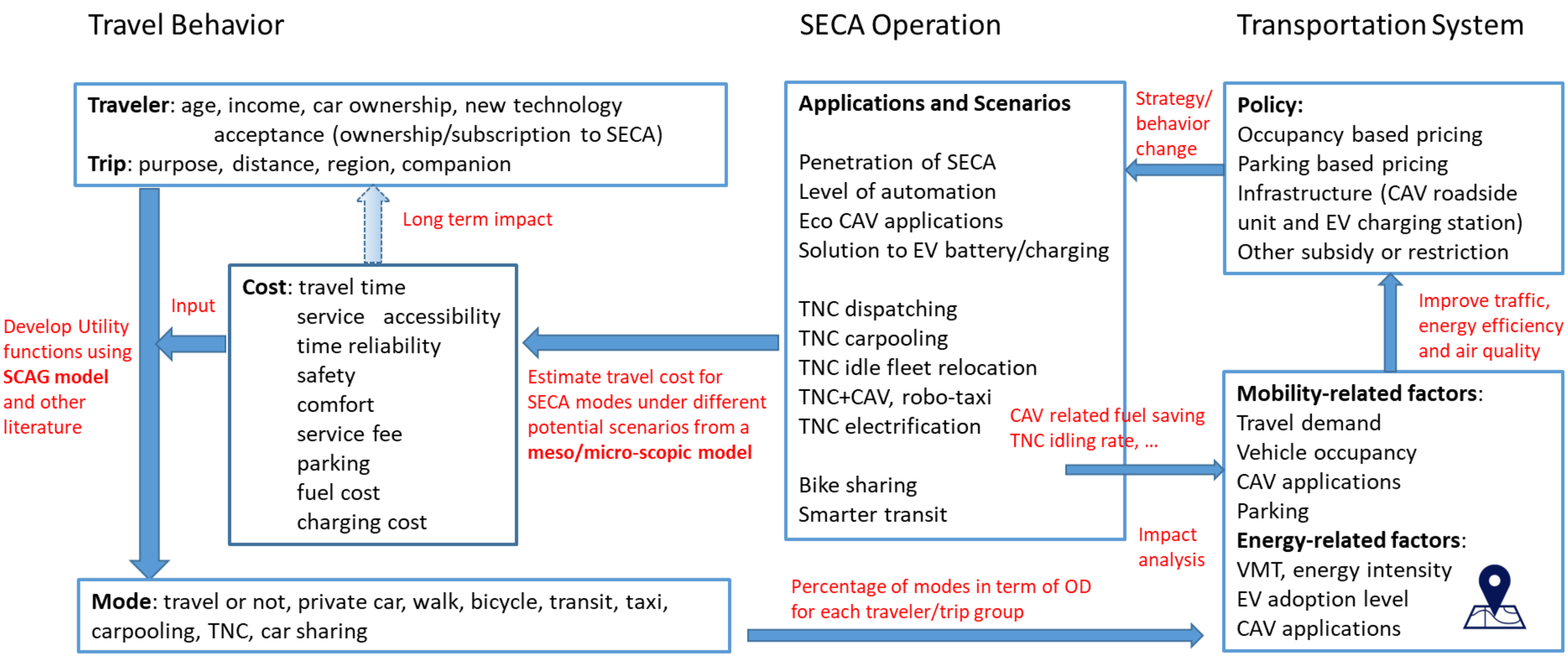
If Not Uber or Lyft, Then What?*

Mode substitution, weighted by frequency of ride-hailing use



Source: UC Davis Institute of Transportation Studies

Accomplishments – Model Framework



Collaboration and Coordination with Other Institutions

- Partner: NREL
  - Support processing and analysis of CAVs-relevant data
  - Support model implementation and energy impact evaluation
- Collaboration with other universities and national labs
  - LBNL: Tom Wenzel
  - UC Berkeley: Susan Shaheen
- Collaboration with agencies and industry
  - Southern California Association of Governments
  - LA Metro
  - City of Riverside
  - City of Sacramento
  - City of Carson
  - Volvo Truck

Remaining Challenges and Barriers

- Difficulty in obtaining automated vehicle data from private companies
- Existing large-scale connected vehicle deployments are mainly for information or safety purposes
- Field data from various CAV experiments and deployments lack consistency and may only be applicable to their own specific scenarios
- Crowd-sourced data from shared mobility application provides an incomplete picture for before-and-after study comparison
- Difficulty in quantifying travel mode choices considering new mobility technologies
- The UCR and NREL Team will work together to address each of the identified challenges/barriers.

Proposed Future Research

- Complete collection and processing of CAV and shared mobility data
- Estimate the impacts on energy intensity due to deployment of CAV technologies on an individual vehicle basis, using the real-world datasets
- Develop new travel behavior modeling that is compatible with the new mobility technologies
- Synthesize the statewide energy inventory framework, taking into account the impacts from CAVs and shared mobility.
- Develop an analysis tool to evaluate the regional and/or statewide energy impacts
- Evaluate the potential effects of proposed policies to mitigate adverse energy outcomes

Summary

- ***This Project:***
  - Collects data from vehicles with CAV and shared mobility technologies (primarily deployed in California)
  - Develops a comprehensive framework for evaluating energy efficiency opportunities from large-scale CAVs and shared mobility systems
  - Addresses key barriers by quantifying the transportation system-wide energy impacts from new mobility technologies using real-world data
- ***Technical Accomplishments and Progress:***
  - Collection and processing of CAV data from real-world experiments and early deployments, supplemented by simulation data
  - Archiving both crowd-sourced and survey data for shared mobility applications
  - Development of the proposed modeling framework

- Solid collaboration with universities, national labs, agencies and industry
- Future research to tackle remaining challenges

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Thank You

Technical Back-Up Slides

Responses to Previous Year Reviewers' Comments

- No comments to respond to from last year as this is a new project