Definition of Connected and Automated Vehicle (CAV) Concepts for Evaluation

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2017 AMR
JUNE 8, 2017
PROJECT OVERVIEW

Timeline
• 35% complete

Barriers Addressed
• Understanding CAV system capabilities
• Estimating energy impacts of CAVs over time

Budget
• $50 K, FY 17 only

Partners
• LBNL lead
• Contributions from other DOE SMART Mobility Labs: ANL, ORNL, NREL, INL
RELEVANCE/ OBJECTIVES

• To have common definitions so people working throughout DOE SMART Mobility can understand each other (talking about the same thing)
  – Avoid vague and misleading terminology
  – Avoid confusion and misunderstanding

• So analyses conducted by researchers in different Pillars and different labs can be compared “apples to apples”
  – Comparable assumptions about system functionalities
  – Comparable assumptions about deployment timing

• Define representative use cases to facilitate comparisons
  – Avoiding unnecessary duplications or overlaps
APPROACH

• Define dimensions of the CAV space
  – Connected vehicles (CV) without automation
  – Driving Automation System dimensions:
    • Connected vs. Unconnected (autonomous)
    • SAE Levels of Automation (driver vs. system roles)
    • Operational Design Domain (ODD)
  – Other attributes:
    • Vehicle class
    • Powertrain technology
    • Business models to govern operations
• Define example concept packages for study
• Estimate timing of market introduction and growth
• CAV Concept Dimensions defined and reviewed and updated with CAV Pillar partner lab inputs

• Example concept packages (use cases) defined and reviewed and updated with CAV Pillar partner lab inputs
CONNECTED VEHICLE (CV) SYSTEMS WITHOUT AUTOMATION

• Independent features, with limited coupling between them – can be analyzed individually:
  
  – V2V cooperative collision warnings
  – V2I/I2V cooperative intersection collision warnings
  – I2V speed advisories
  – V2V cooperative driving information
  – V2I/I2V route planning, parking information and reservations (eco-routing)
  – I2V local traffic signal phase and timing information (eco-signal control, signal priority requests)
DRIVING AUTOMATION SYSTEMS – KEY DIMENSIONS (CLOSELY COUPLED FOR IMPACT ESTIMATION)

• Connected or Unconnected (Cooperative vs. Autonomous)

• SAE Levels of Automation (http://standards.sae.org/j3016_201609/)
  – L0: No sustained automation, no change in driver role
  – L1: Driver Assistance (lateral OR longitudinal control)
  – L2: Partial Automation (lateral AND longitudinal control under continuous driver supervision)
  – L3: Conditional Automation (lateral AND longitudinal control plus object and event detection and response, driver fallback)
  – L4: High Automation (automation of all dynamic driving task functions, but limited to within an Operational Design Domain (ODD))

• Operational Design Domain
OPERATIONAL DESIGN DOMAIN (ODD)

The specific conditions under which a given driving automation system or feature thereof is designed to function, including:

- Roadway type
- Traffic conditions and speed range
- Geographic location (within boundaries of digital map)
- Weather and lighting conditions
- Availability of necessary supporting infrastructure features
- Condition of pavement markings and signage
- Ability to cope with anomalies or foreign objects
- (and potentially more…)
EXAMPLE OF IMPORTANCE OF CONNECTIVITY TO PERFORMANCE

• Production autonomous ACC response (4 vehicles):

• Cooperative ACC (CACC) response to same disturbance:
VEHICLE CLASSES

• Passenger
  – Ultralight (1-2 passengers)
  – Light Duty (3-9 passenger capacity)
  – Medium Duty (10-20 passengers)
  – Heavy Duty (full-size buses)

• Freight
  – Ultralight (few kilogram capacity)
  – Light Duty (Class 1-3 trucks)
  – Medium Duty (Class 4-6 trucks)
  – Heavy Duty (Class 7-8 trucks)
• Largely decoupled from the other dimensions for analysis:
  – Gasoline
  – Diesel
  – Natural gas
  – Hydrogen fuel cell
  – Hybrid gasoline or diesel
  – Plug-in hybrid
  – Battery electric
  – Externally-supplied electricity (catenary or inductive)
BUSINESS MODELS

• Private ownership and use
• Short-term rental / car-share (Zipcar, Getaround, Car2Go, etc.)
• Transportation network company (TNC = Uber, Lyft, conventional taxi, etc.)
• Public transit-like (fixed or semi-fixed route & timetable, possibly with first/last-mile capability)
• Private goods delivery
• Common carrier goods delivery
EXAMPLE CONCEPTS RECOMMENDED FOR STUDY (1/2)

• I2V cooperative eco-driving support (L0)
• Laterally guided bus on busway (L1)
• Highly automated bus on busway (L4)
• Semi-fixed route automated shuttle (L4)
• First-generation low-speed automated urban taxi (L4)
• Advanced automated taxi (L4)
• Basic truck platooning (L1)
• Advanced truck platooning (L1 leader, L3/L4 followers)
• Low-speed urban goods distribution robot (L4)
• Cooperative ACC or platooning for passenger cars (L1)
• Urban eco-signal control with I2V signal information (L1)
• Urban freeway automated driving (L4)
• Intercity freeway automated driving (L4)
• Automated highway system (L4 in dedicated, segregated lanes)
COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS

• LBNL initially defines draft document on each topic

• Circulate draft among CAV Pillar lab representatives for comments and discuss in conference call
  – ANL (lead), ORNL, NREL, INL

• Update draft based on inputs received

• Circulate to other DOE SMART Mobility Pillar representatives for their review and use
  – Mobility Decision Science (LBNL lead)
  – Urban Science (NREL lead)
  – Multi-modal (ORNL lead)
  – Vehicles and Infrastructure (INL lead)
RESPONSES TO PREVIOUS YEAR REVIEWERS’ COMMENTS

• New start – no previous year comments
REMAINING WORK: ESTIMATING TIMING OF AVAILABILITY

- Impacts depend on a sequence of actions, with significant time lags at each step:
  - Initial availability based on technical feasibility, safety
  - Rate of growth among new vehicle market
  - Potential for retrofits into existing vehicles
  - Turnover of full vehicle fleet
  - Actual utilization by drivers/travelers using equipped vehicles

- Historical data from prior vehicle technology changes provide initial guidance on lag times
NEXT STEPS (BALANCE OF FY17)

• Definition of estimates of timing for availability of each example concept, considering large uncertainties:
  – Study years 2030, 2040, 2050
  – Low, medium and high market penetration assumptions in each year for sensitivity studies

• Outreach to researchers in other pillars for their use in DOE SMART Mobility studies
SUMMARY

• Basic dimensions for characterizing connected and automated vehicle (CAV) systems have been defined

• Example use cases (or concepts) have been defined as a basis for evaluation studies

• Estimates of fast, medium and slow deployment profiles for each example concept are in process

• Outreach beyond CAV Pillar to other DOE SMART Mobility Pillars will follow, to seek consistency across studies
QUESTIONS?