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Driving Innovation

Federal Highway Administration (FHWA) Research on Emerging Technology Modeling

Transportation Research Board (TRB)
Workshop on Traffic Simulation and Connected and Automated Vehicle (CAV) Modeling
November 16–18, 2020

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U.S. Department of Transportation
Federal Highway Administration

SAXTON LABORATORY

Outline

- Motivation.
- Approach.
- Challenges.
- Data, Model Improvement, and Benefits Estimation.
- Collaboration Examples.
- Conclusions.

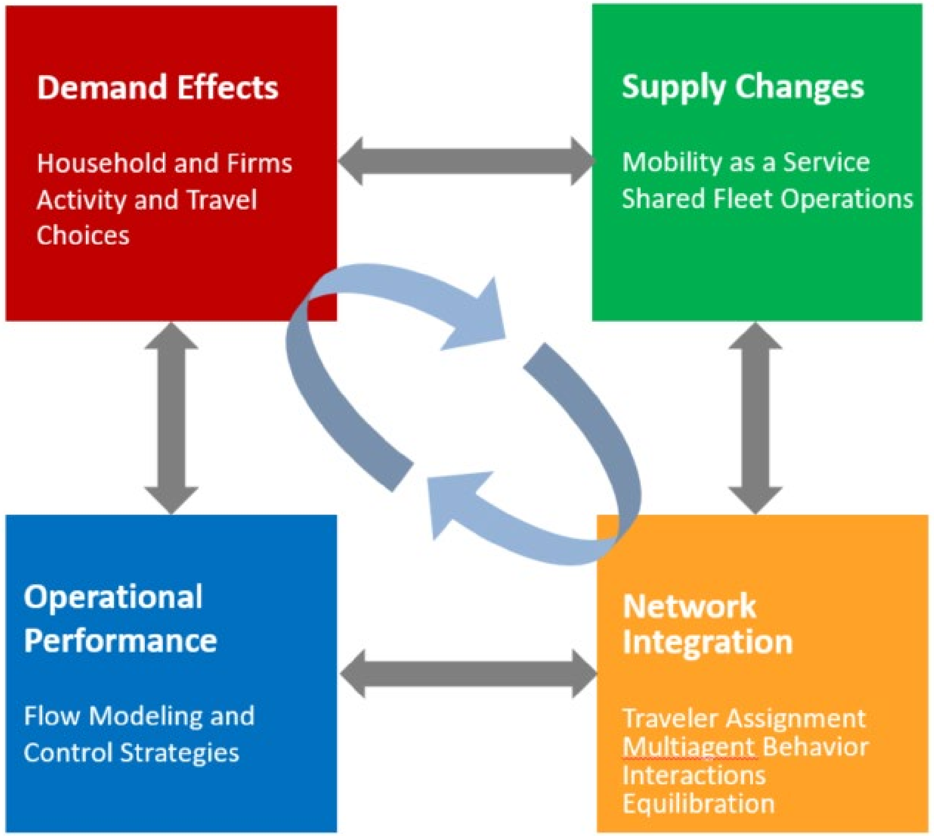
Motivation: Modeling Impacts of CAVs

- Agencies need a low-cost approach to quantify impacts of CAV deployments to make intelligent investment and operational decisions.
- Traffic analysis tools provide an efficient approach to evaluate a new technology or strategy prior to implementation.
- Current modeling and simulation tools were built to model human driving behavior.
- New CAV behavioral models for microsimulation tools are rapidly under development.

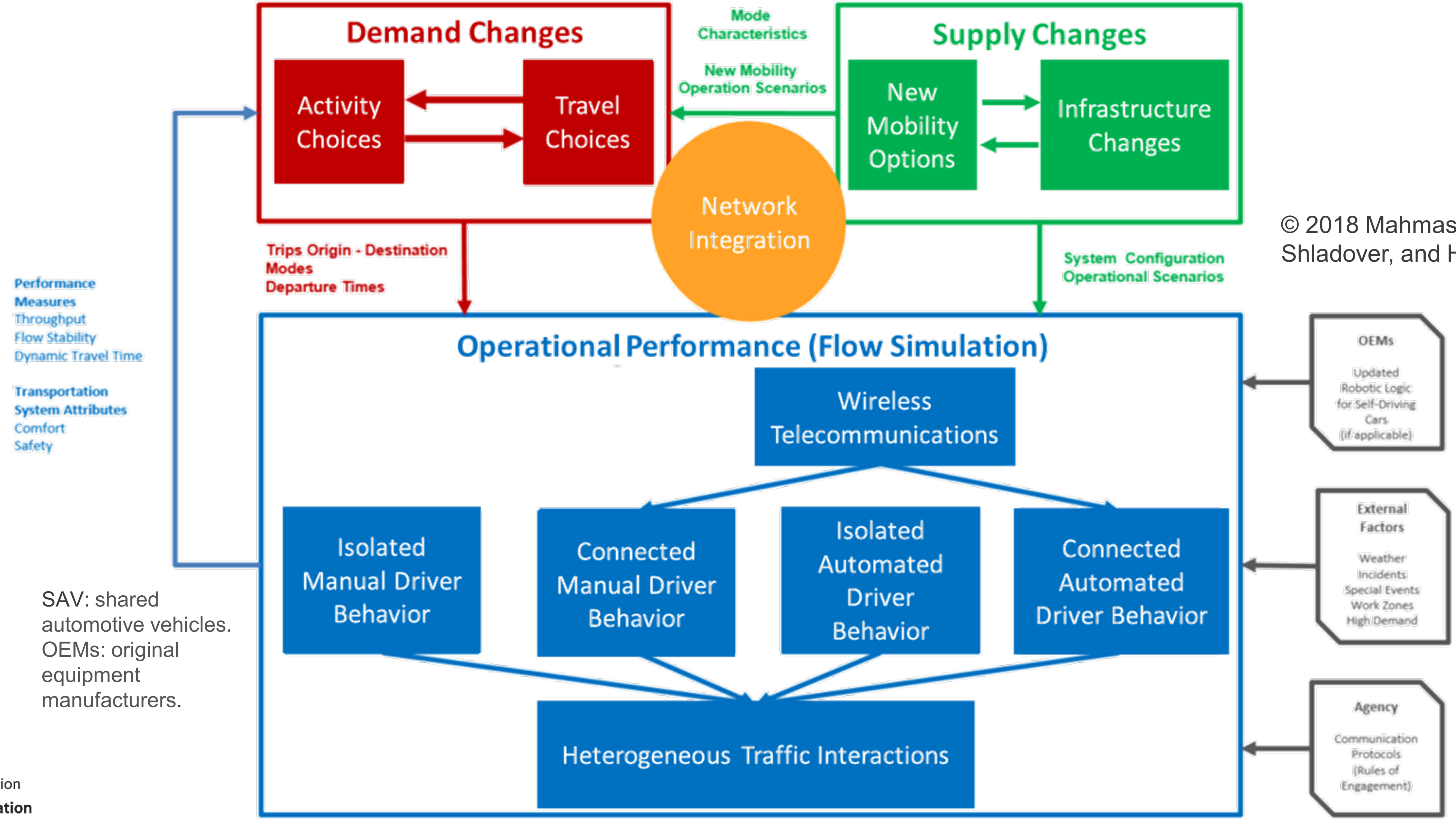
Approach: CAV Analysis, Modeling, and Simulation (AMS) Framework and Gap Analysis

Objectives:

- Build comprehensive methodological framework for developing AMS tools that incorporate the impacts of CAVs.
- Conduct an analysis identifying gaps in existing CAV AMS capabilities.

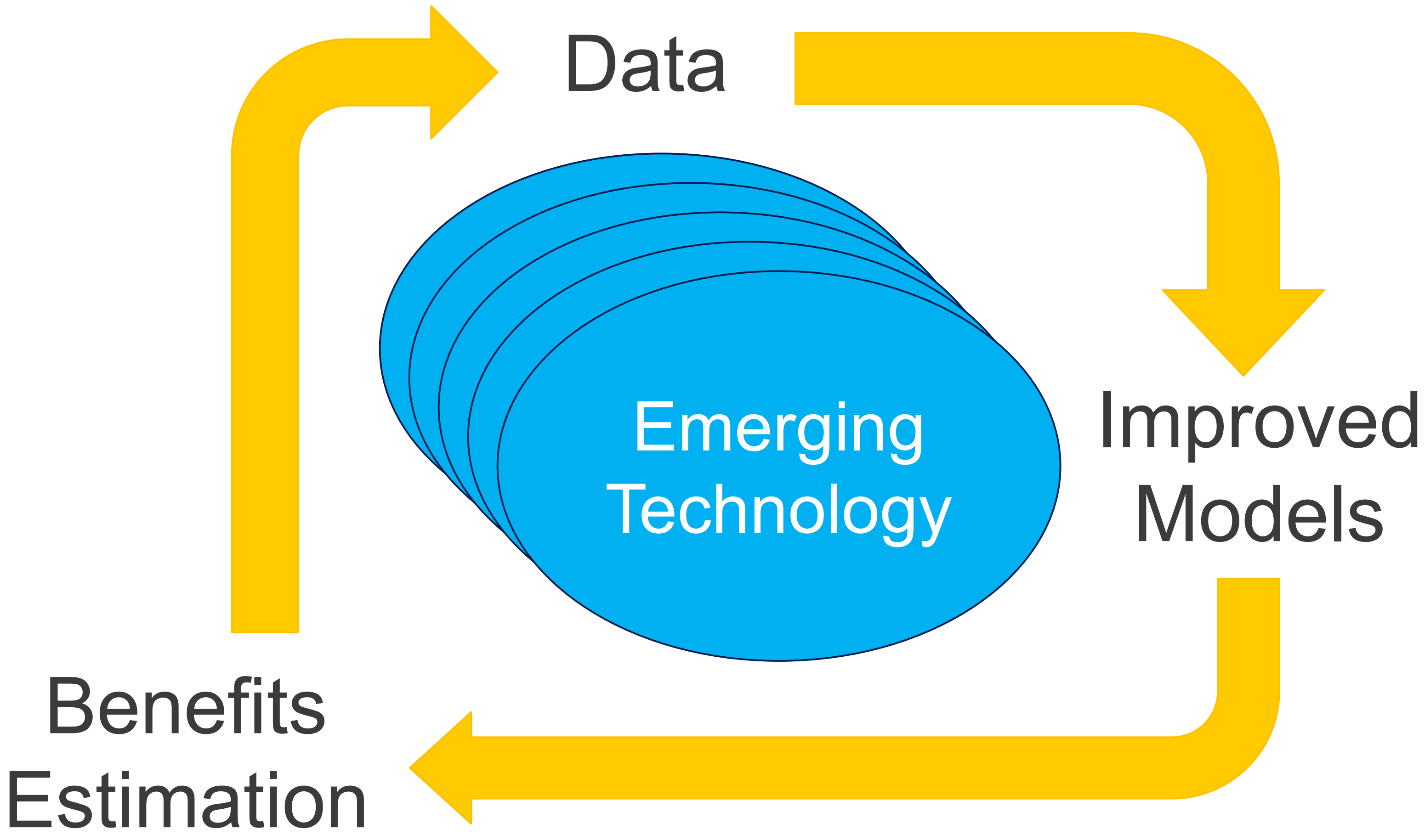


Approach: CAV AMS Framework and Gap Analysis



SAV: shared automotive vehicles. OEMs: original equipment manufacturers.

Challenges

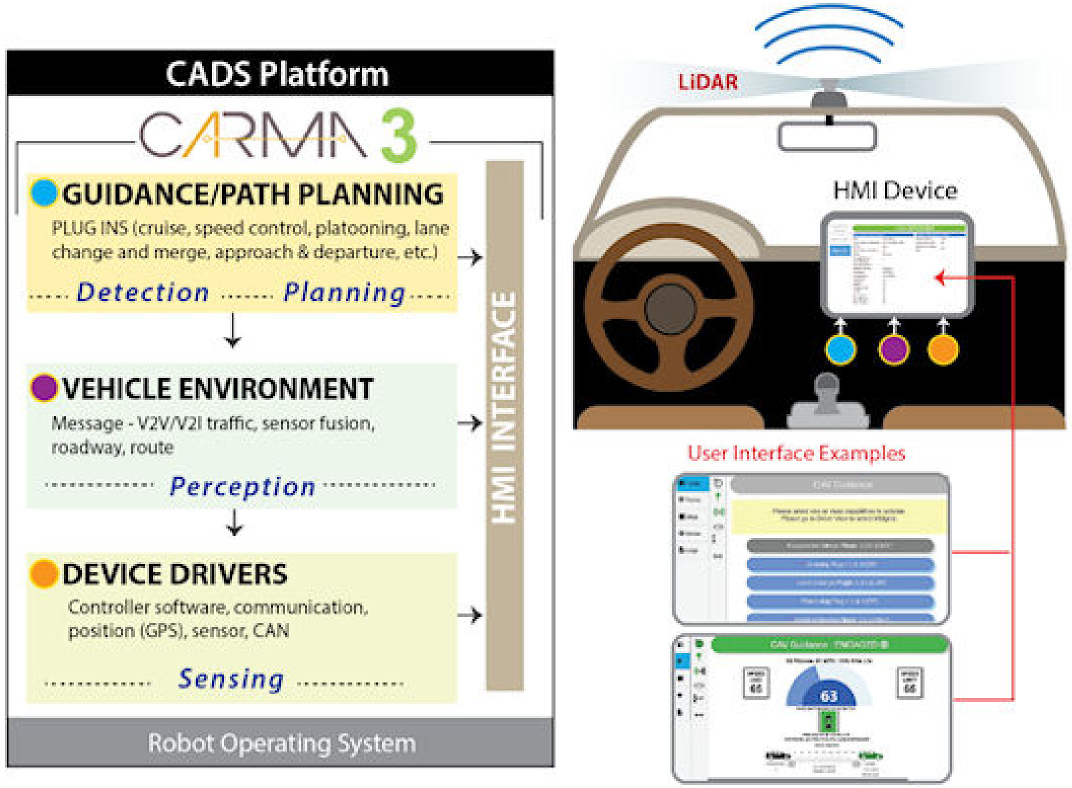


Source: FHWA.

Data: CARMA3SM L3 Class A–D Vehicle and Surrounding Vehicles

Collect a robust dataset about the behavior of a CARMA3 vehicle and a human-driven vehicle in naturalistic traffic conditions.

- Collected data will provide complete details regarding the adjacent vehicles surrounding the subject vehicle(s).
- Subject vehicles will be deployed in similar traffic conditions during a data run.



Source: FHWA.

CADS = cooperative automated driving system.
V2V = vehicle-to-vehicle.
V2I = vehicle-to-infrastructure.
GPS = global positioning satellite.
CAN = controller area network.
LiDAR = light detection and ranging.
HMI = human machine interface.

New SAE International Cooperative Driving Automation (CDA) Framework—J3216

- Classes of Cooperative Automation:
  - A—Status Sharing.
  - B—Intent Sharing.
  - C—Agreement Sharing.
  - D—Prescriptive.
- Challenges and opportunities for AMS?

RELATIONSHIP BETWEEN CLASSES OF COOPERATIVE DRIVING AUTOMATION (CDA) J3216 AND LEVELS OF AUTOMATION J3016

CDA CLASSES		PARTIAL AUTOMATION OF DDT			COMPLETE AUTOMATION OF DDT		
		SAE LEVEL 0	SAE LEVEL 1	SAE LEVEL 2	SAE LEVEL 3	SAE LEVEL 4	SAE LEVEL 5
		No Driving Automation (human does all driving)	Driver Assistance (longitudinal OR lateral vehicle motion control)	Partial Driving Automation (longitudinal AND lateral vehicle motion control)	Conditional Driving Automation	High Driving Automation	Full Driving Automation
NO COOPERATIVE AUTOMATION		e.g., Signage, TCD	Relies on driver to complete the DDT and to supervise feature performance in real time		Relies on ADS to perform complete DDT under defined conditions (fallback condition performance varies between levels)		
SAE CLASS A STATUS SHARING	Here I am and what I see	e.g., Brake Lights, Traffic Signal	Potential for improved object and event detection[1]		Potential for improved object and event detection[2]		
SAE CLASS B INTENT SHARING	This is what I plan to do	e.g., Turn Signal, Merge	Potential for improved object and event prediction[1]		Potential for improved object and event prediction[2]		
SAE CLASS C AGREEMENT SEEKING	Let's do this together	e.g., Hand Signals, Merge	N/A		C-ADS designed to attain mutual goals through coordinated actions		
SAE CLASS D PRESCRIPTIVE	I will do as directed	e.g., Hand Signals, Lane Assignment by Officials	N/A		C-ADS designed to accept and adhere to a command		

1 Improved object and event detection and prediction through CDA Class A and B status and intent sharing may not always be realized, given that Level 1 and 2 driving automation features may be overridden by the driver at any time, and otherwise have limited sensing capabilities compared to Level 3, 4 and 5 ADS-operated vehicles.

2 Class A and B communications are one of many inputs to an ADS's object and event detection and prediction capability, which may not be improved by the CDA message.

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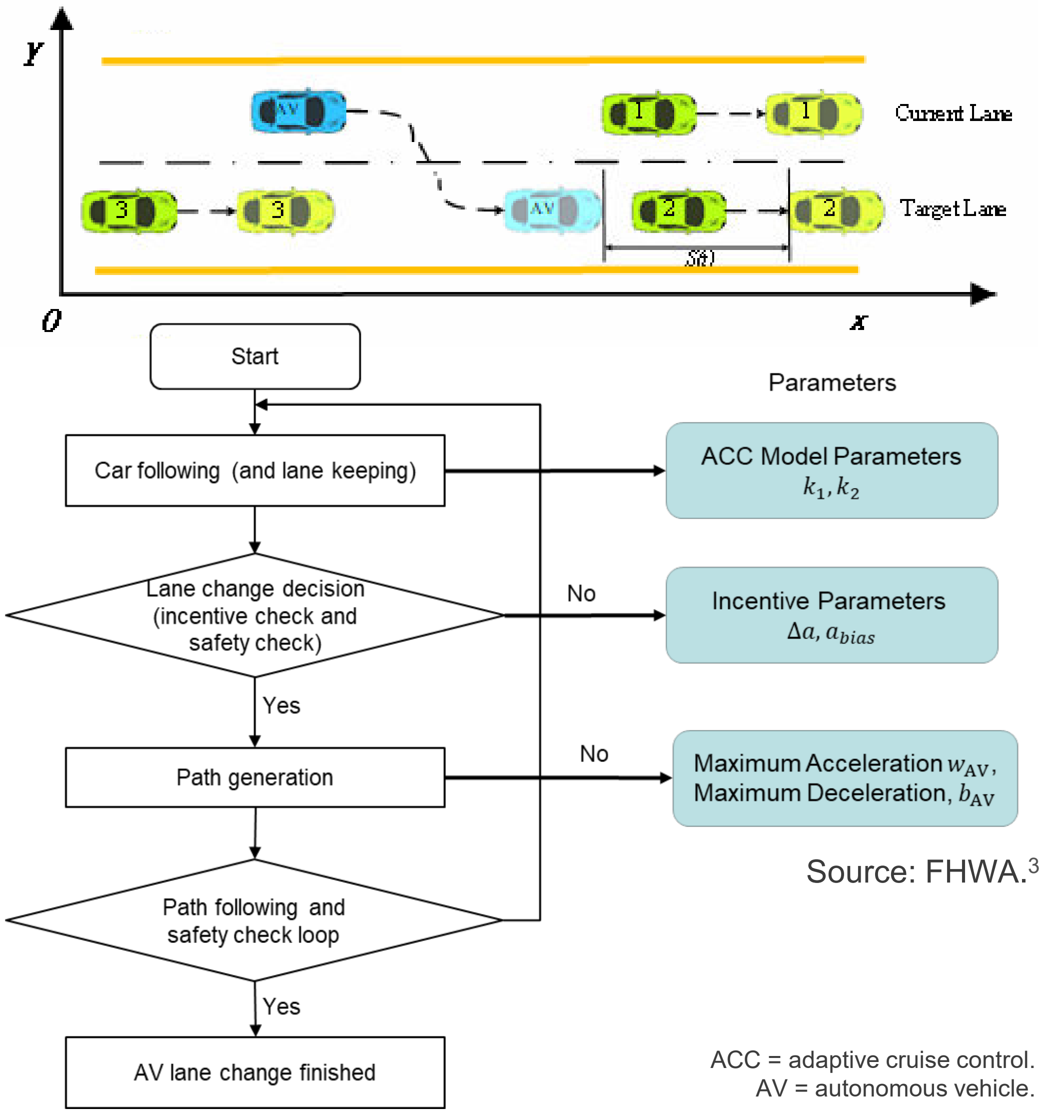
Data: New Awards

- Broad Agency Announcement (BAA): "Acquiring Connected and Automated Vehicle (CAV) Performance Datasets." (USDOT FHWA Notice ID 693JJ3-20-BAA-0005)
- Full and Open Competition.
- Seeking Datasets:
  - Advanced Driver Assistance Systems (ADAS) and Automated Driving Systems (ADS).
  - Subject vehicle and surrounding vehicle trajectories.
- Selected Awardee(s).

Model Improvement: Tools Development

- Focus is on developing new tools to enable more robust impact assessments.
- Open-source tools are being developed:
  - Automated vehicle lane-changing algorithm.
  - Improved cooperative adaptive cruise control algorithm and connected vehicle algorithm.
  - Improved speed harmonization algorithm.
  - Cooperative merge algorithm.



Source: FHWA.[3]

ACC = adaptive cruise control.
AV = autonomous vehicle.

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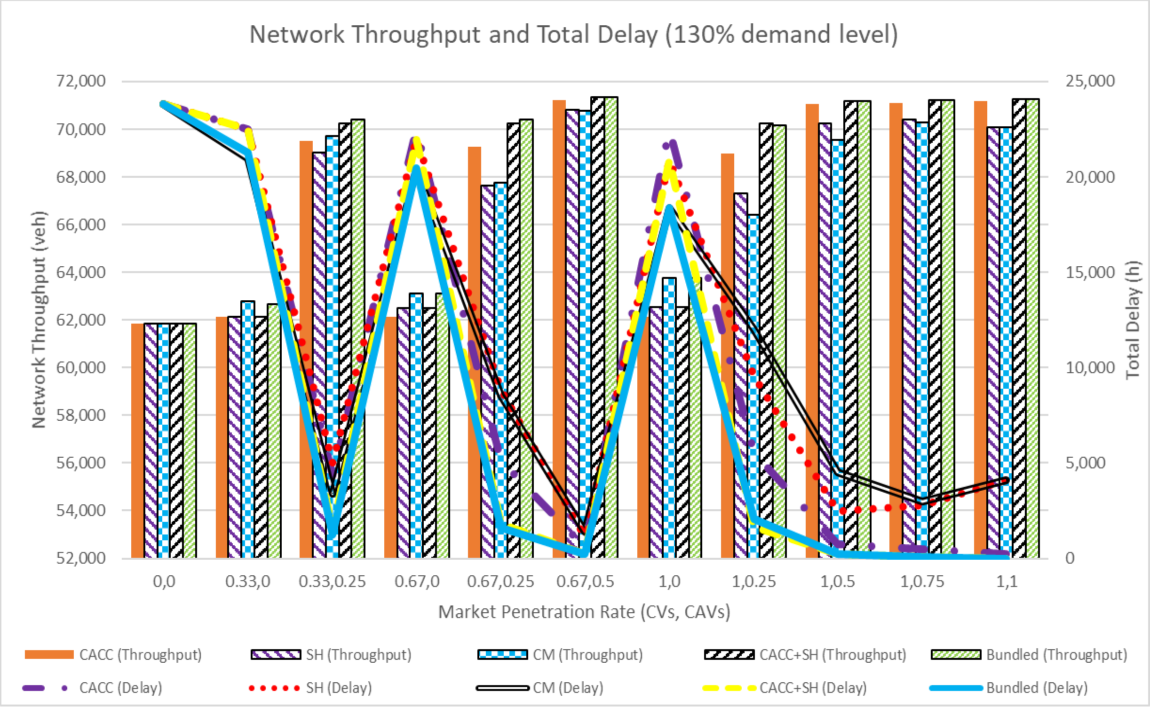
Benefits Estimation: Case Studies

- Benefits assessment using *existing* tools and capabilities.
- Local agencies are involved to ensure simulations represent realistic, near-term deployments.
- Freeway case studies:
  - I–66.
  - SR–99.
- Arterial case studies:
  - Ann Arbor, MI.
  - Conroe, TX.

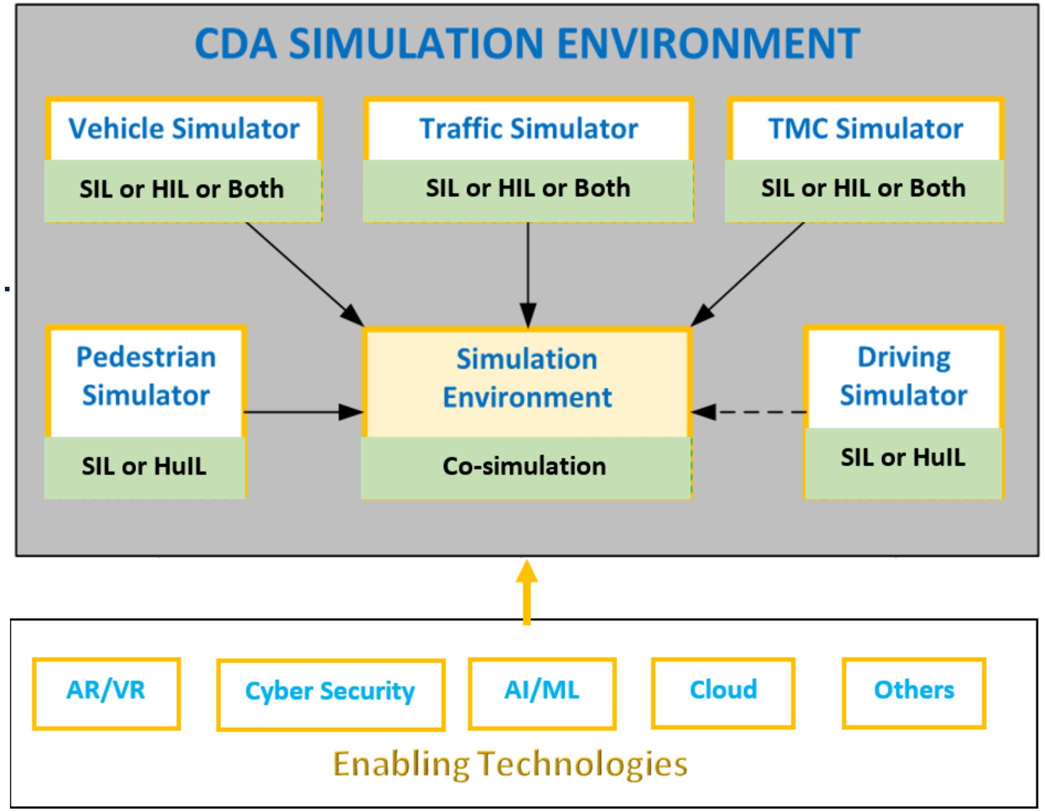


CACC = cooperative adaptive cruise control.
CAV = connected automated vehicle.
CM = cooperative merge.
CV = connected vehicle.
SH = speed harmonization.

Source: FHWA.[4]

Approach: FHWA CDA Simulation Environment

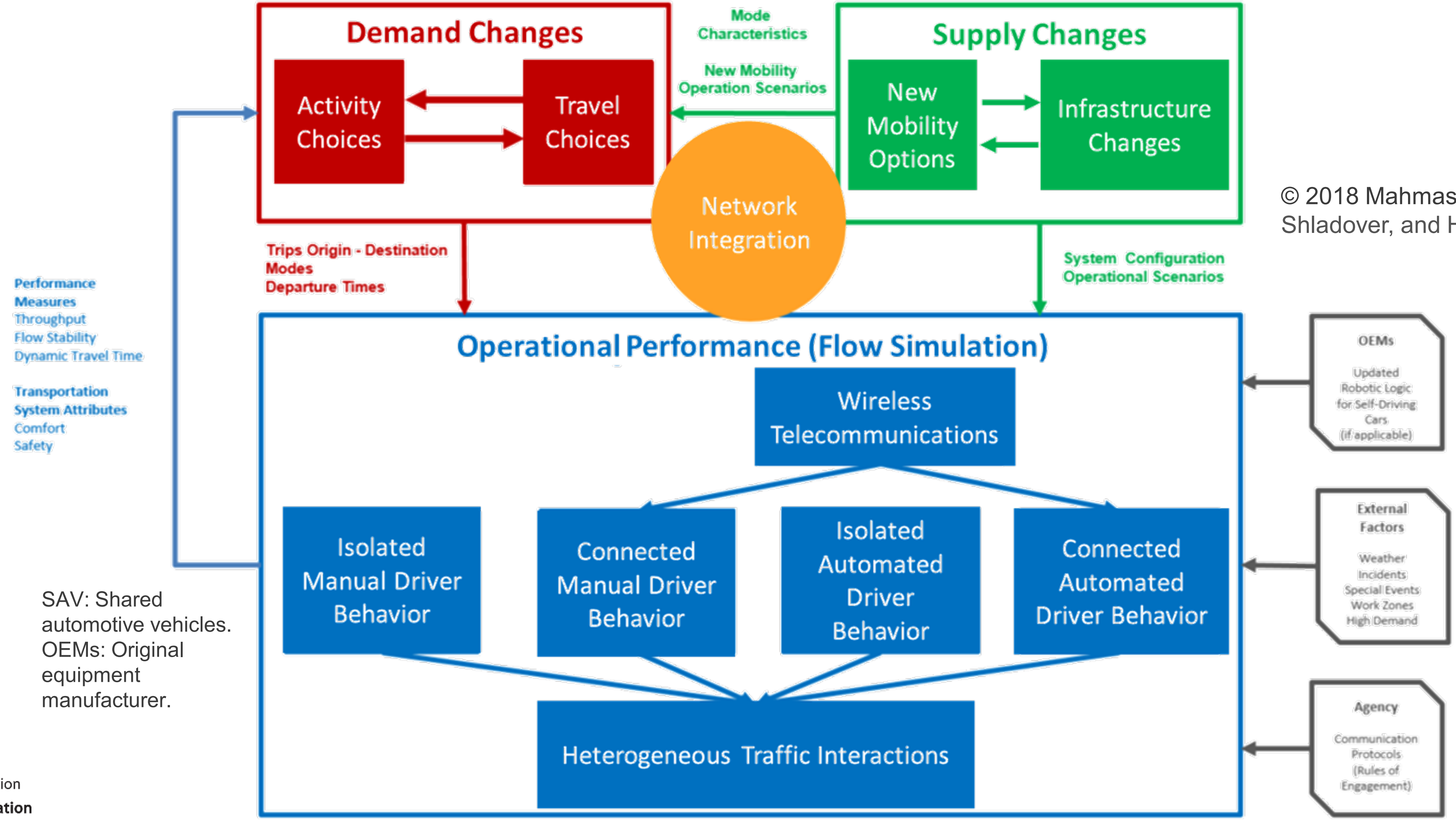
- A multisimulation-focused evolutionary framework for progressing CDA simulation capabilities.
- Supports sophisticated simulation of CDA/CARMA for efficient and effective development, testing, and evaluation.
- Key simulators:
  - Vehicle simulator: CARLA.
  - Traffic simulator: SUMO (research) or PTV Vissim/Aimsun® (industry).
  - Transportation Management Center (TMC) simulator: CARMA Cloud℠.
  - Pedestrian simulator.
  - Driving simulator: Turner-Fairbank Highway Research Center (TFHRC) Highway Driving Simulator (HDS) or National Advanced Driving Simulator (NADS) miniSim™.
  - Simulation Environment: CARMA Simulation Environment.
- Key enabling technologies:
  - Augmented reality (AR)/virtual reality (VR).
  - Cybersecurity.
  - Artificial intelligence (AI)/machine learning (ML).
  - Cloud computing.



Source: FHWA.

SIL = software-in-the-loop.
HIL = hardware-in-the-loop.
HuIL = human-in-the-loop.

Approach: CAV AMS Framework and Gap Analysis



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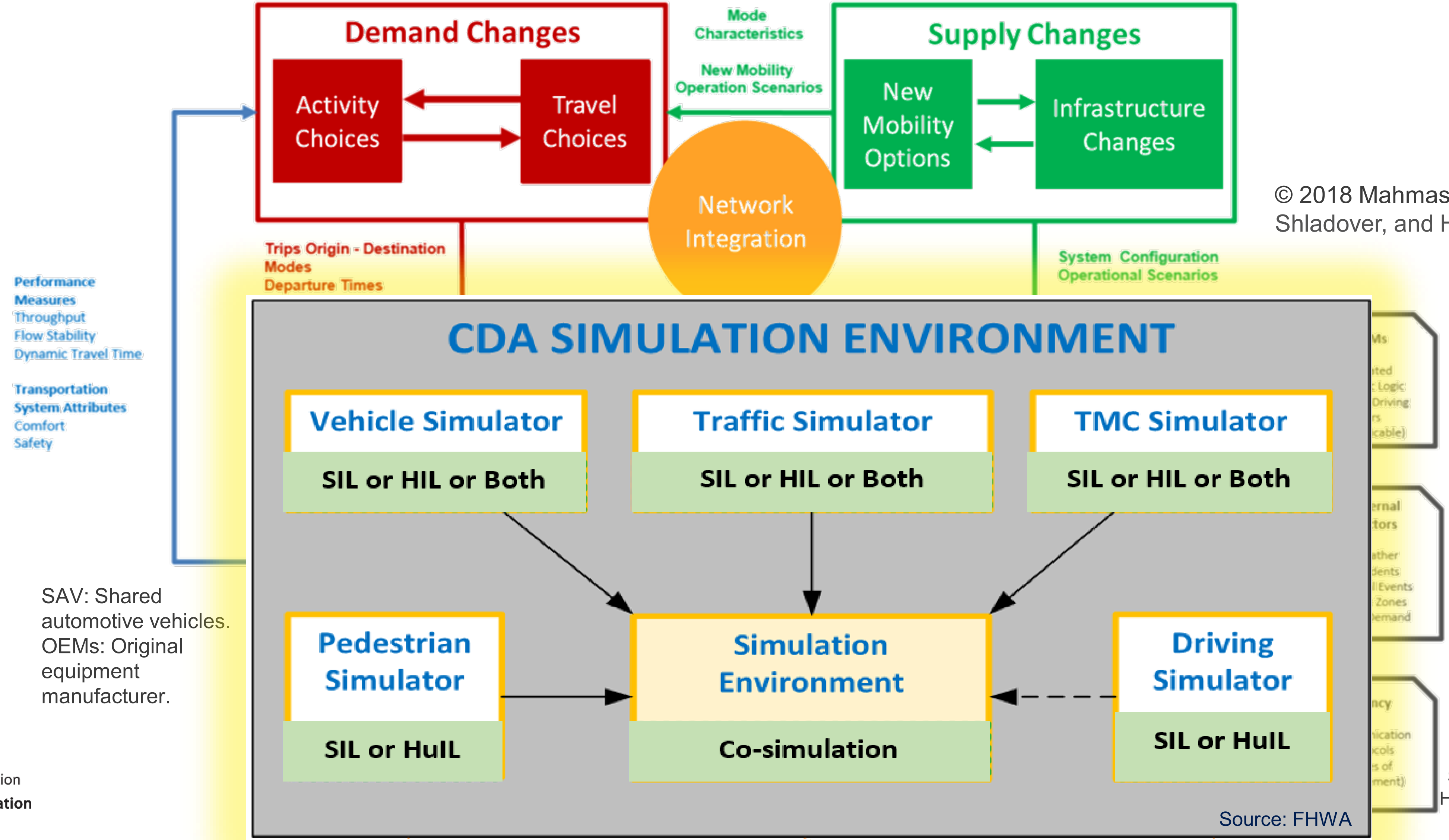
“X” in the Loop (XiL) Role in AMS



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Collaboration Examples

- Stakeholder Groups
- TRB Committees.
- Institute of Transportation Engineers (ITE) Simulation and Capacity Analysis User Group (SimCap).
- AMS Pooled Fund Study: One of the Four Charter Topics: “Evaluation of Innovation Applications.”
- Twinning with European Commission’s CoEXist® project.
- U.S. Department of Energy collaboration.

Conclusions

- Microsimulation tools were developed to model human driver behavior. New tools are needed to appropriately emulate CAV driving behavior and human drivers' response to this behavior.
- FHWA has funded several recent efforts related to AMS and CAVs. Many of these efforts will be featured in the workshop.
- FHWA is continuing efforts on data, model improvements, and benefits estimation to support the needs of the broader stakeholder community.

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1. Mahmassani, H.S., Elfar, A., Shladover, S., and Huang, Z. (2018). *Development of an AMS Framework for Connected and Automated Vehicles.* United States Department of Transportation. Washington, D.C. Available at: https://rosap.ntl.bts.gov/view/dot/39965.
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3. Lu, X., Liu, H., Li, X., Li, Q., Mahmassani, H., Talebpour, A., Hosseini, M., Huang, Z., Hale, D.K., and Shladover, S.E. (Forthcoming). Developing Analysis, Modeling, and Simulation Tools for Connected and Automated Vehicle Applications. FHWA. Washington, D.C.
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Questions?

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