# Evaluating Energy and Emissions Impacts of Cooperative Adaptive Cruise Control (CACC) Technology through Traffic Microsimulations

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Automated Vehicles Symposium 2017

Breakout 9: Effects of Vehicle Automation on Energy-Usage and Emissions

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Volpe The National Transportation Systems Center

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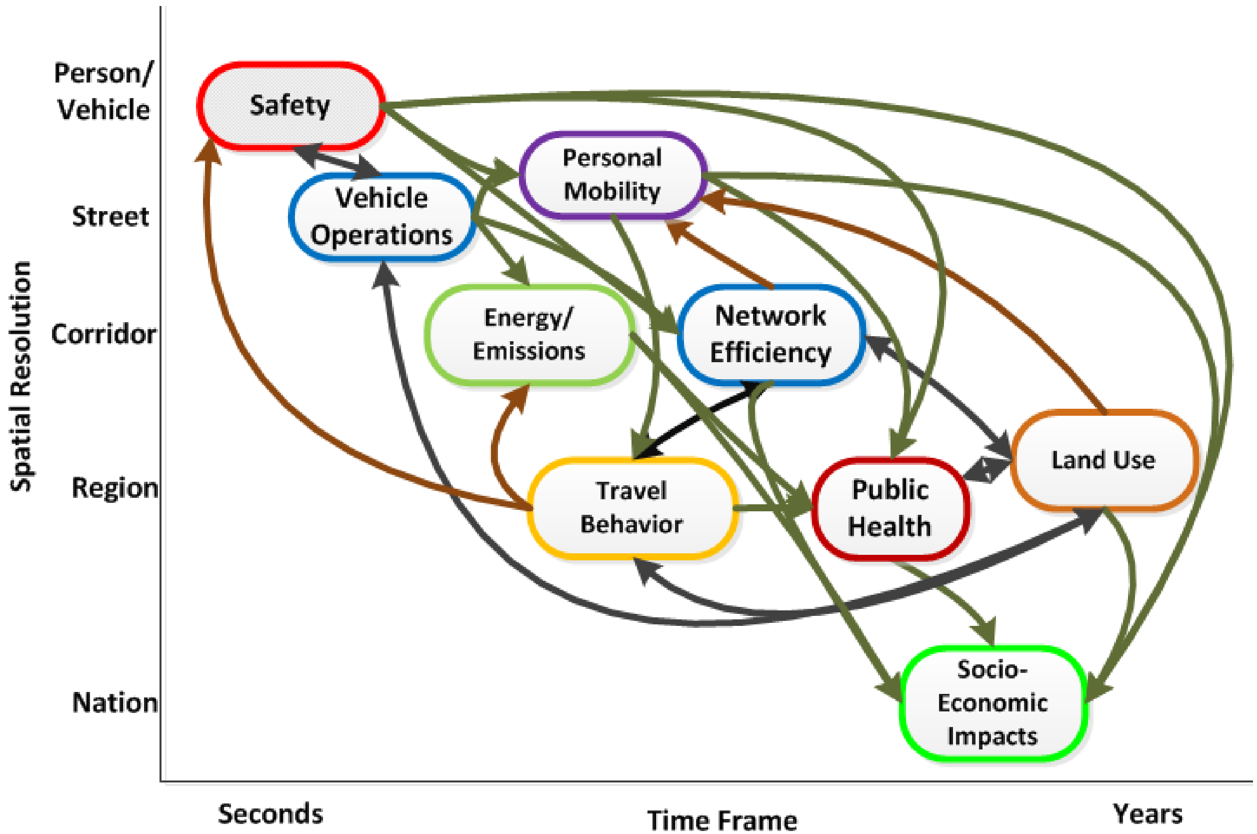
# Framework for Automated Vehicle Benefits

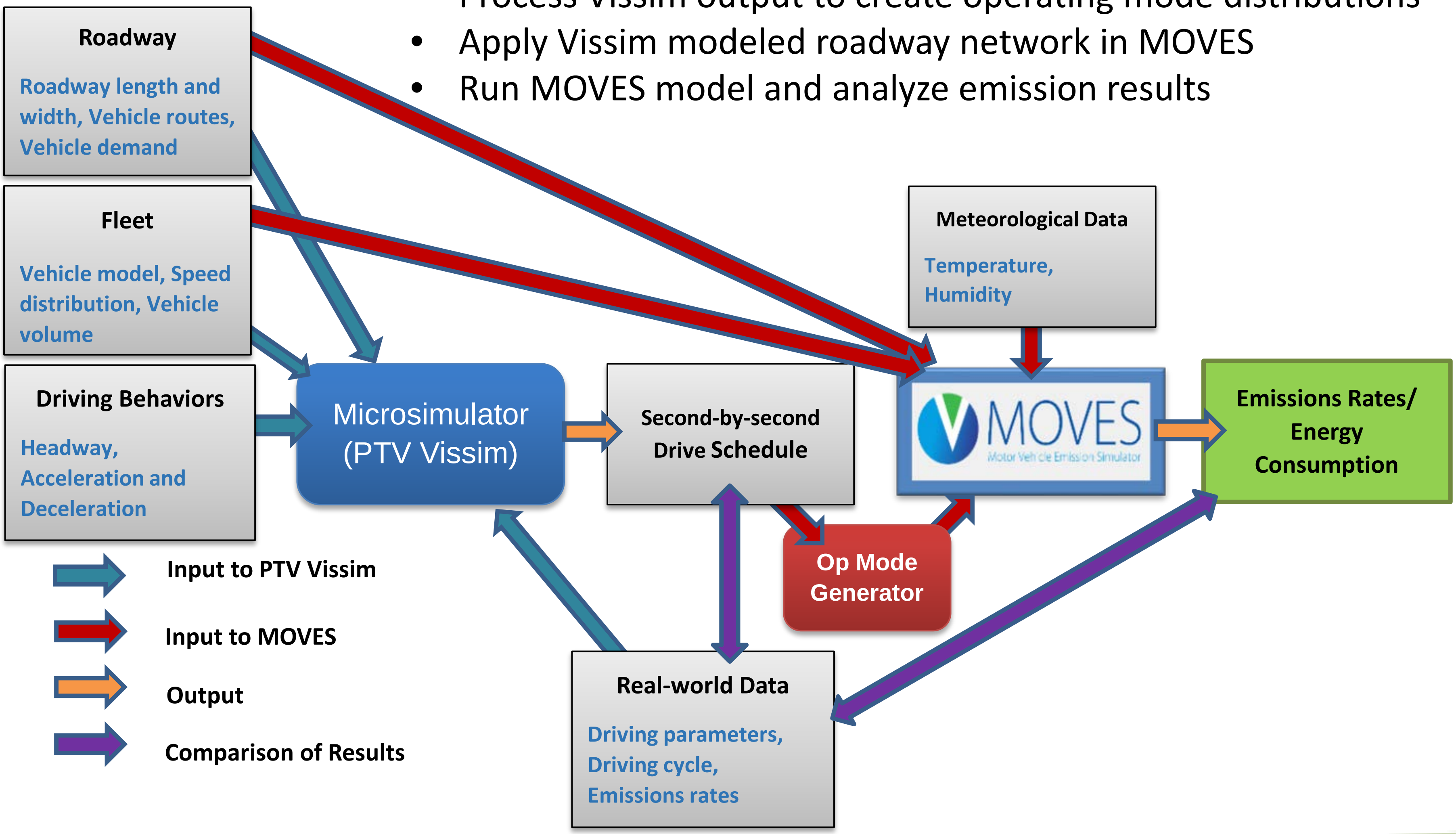
- "Big picture" of automated vehicle impacts
- Short-term direct impacts
- Longer-term indirect impacts




- Focus on the relationship between the vehicle operations and energy/emissions
- Connected a traffic microsimulation software (PTV Vissim) with EPA's emission inventory model for highway vehicles (MOVES)

# Modeling Approach

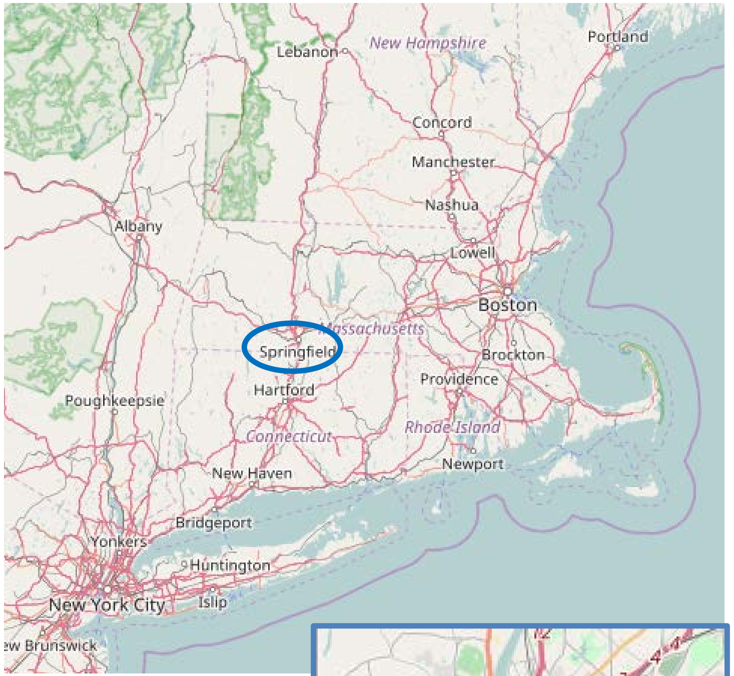
- Produce 15 random Vissim seeds from speed distribution
- Process Vissim output to create operating mode distributions
- Apply Vissim modeled roadway network in MOVES
- Run MOVES model and analyze emission results



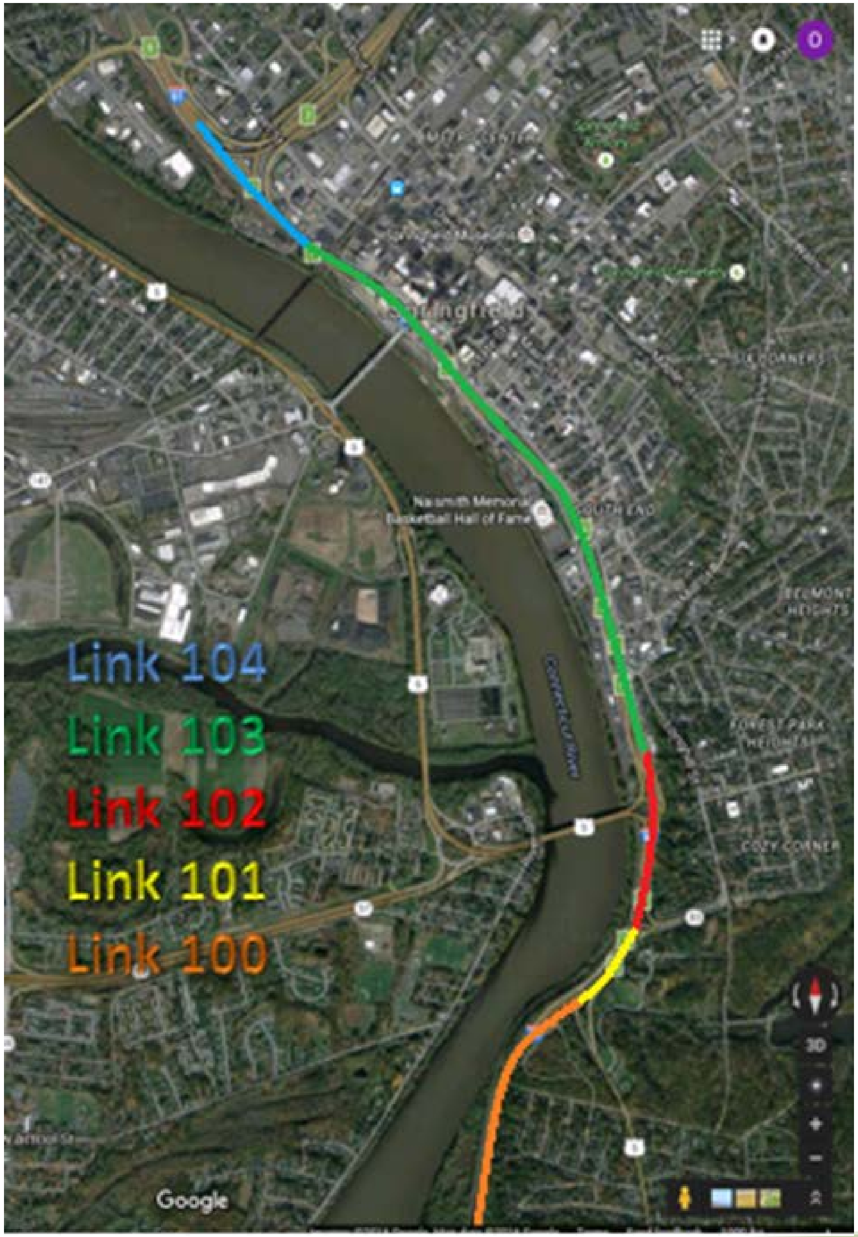
# Vehicle Automation Scenarios

- Modeled passenger cars on Interstate 91 northbound near Springfield, MA
- Speeds and traffic volumes from MassDOT
  - Speed data from sensor on I-91 north of Springfield, MA
  - Volume data from peak weekday morning hour by highway segment
- Modified CACC Driver Model DLL from Turner-Fairbank Highway Research Center (FHWA)
  - Does not include platooning, lane change, or designated lane
- Ran three different microsimulation scenarios in Vissim:
  1) Baseline with default Wiedemann 99 car-following algorithm
  2) All vehicles using CACC driver model
  3) Default Wiedemann 99 algorithm with traffic oscillations set to zero
- MOVES project-level emissions calculated on a per vehicle basis for each scenario (grams/vehicle/hour)

# Map of I-91 Network





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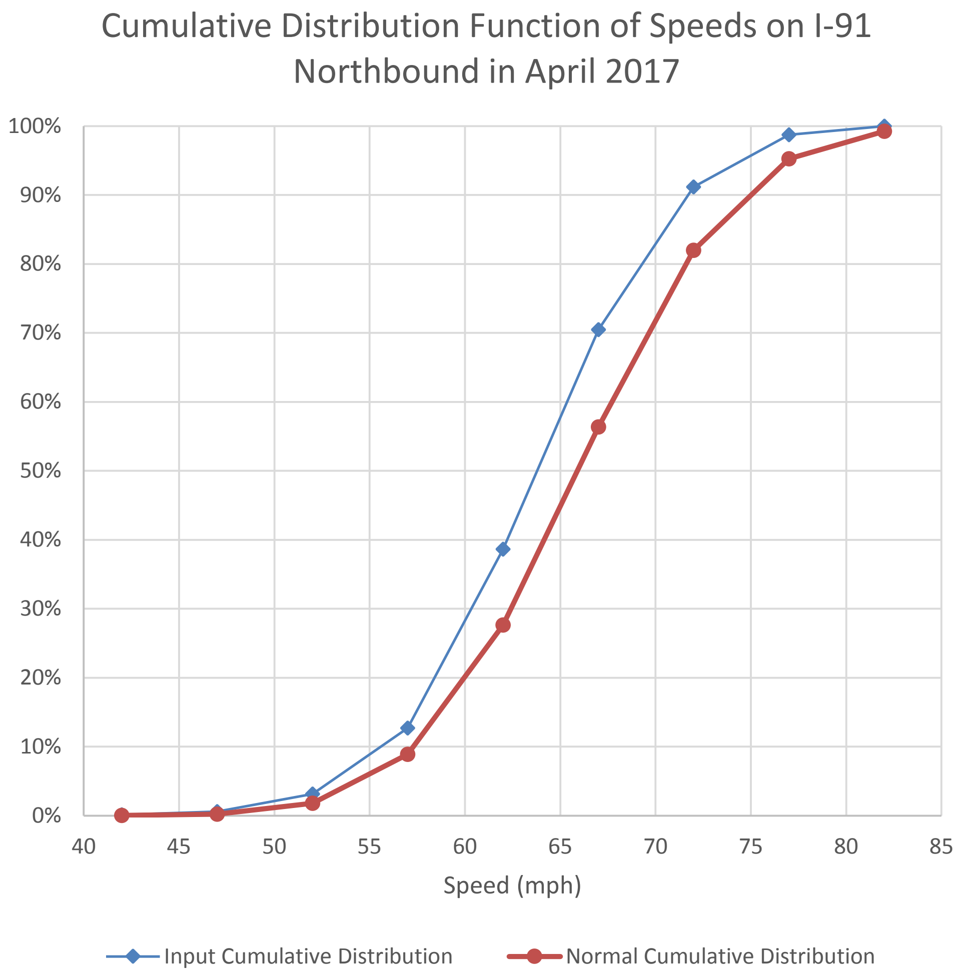
# Input I-91 Traffic Speeds and Volumes



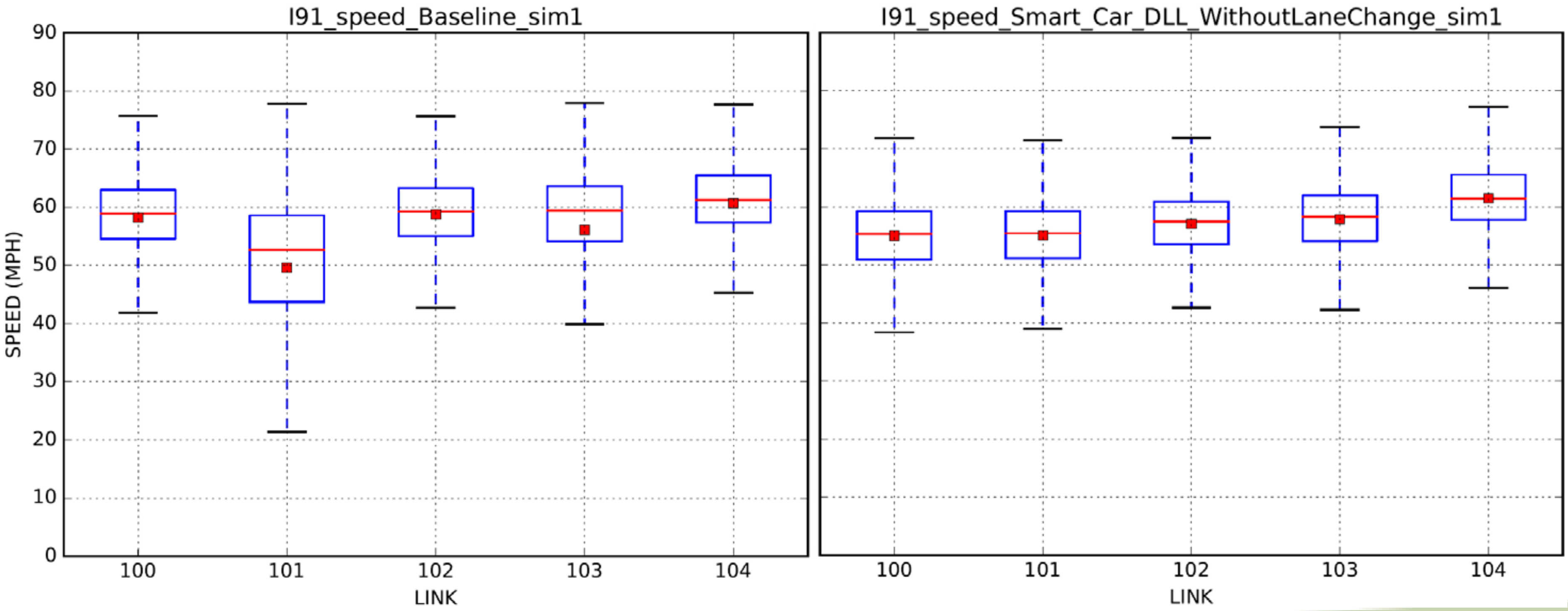

## Input Volumes for Northbound I91 Network

| Link ID | Link Description | Date | Day of Week | AM Peak Time | AM Peak Volume |
|---|---|---|---|---|---|
| 100 | 1. I91 North | 3/10/2017 | Friday | 7:00-8:00 | 2562 |
| 200 | On Ramp (US-5, I91 North, Holyoke, Greenfield) | 7/9/1997 | Wednesday | 7:00-8:00 | 714 |
| 205 | On Ramp (US-5 to I91 North) | 11/13/2001 | Monday | 7:00-8:00 | 1045 |
| 305 | Off Ramp (Exit 3/North 5 to 57, Agawam) | 4/17/2015 | Friday | 7:00-8:00 | 317 |
| 209 | On Ramp (I91 North, Holyoke, Greenfield) | 4/17/2015 | Friday | 7:00-8:00 | 351 |
| 210 | On Ramp (I91 North, Holyoke, Greenfield) | 4/17/2015 | Friday | 7:00-8:00 | 92 |

# Network Performance

- **Box plots of speeds for each link**
  - **25th percentile, median, 75th percentile, mean (red dot)**

**Baseline** **CACC**



# MOVES Operating Modes

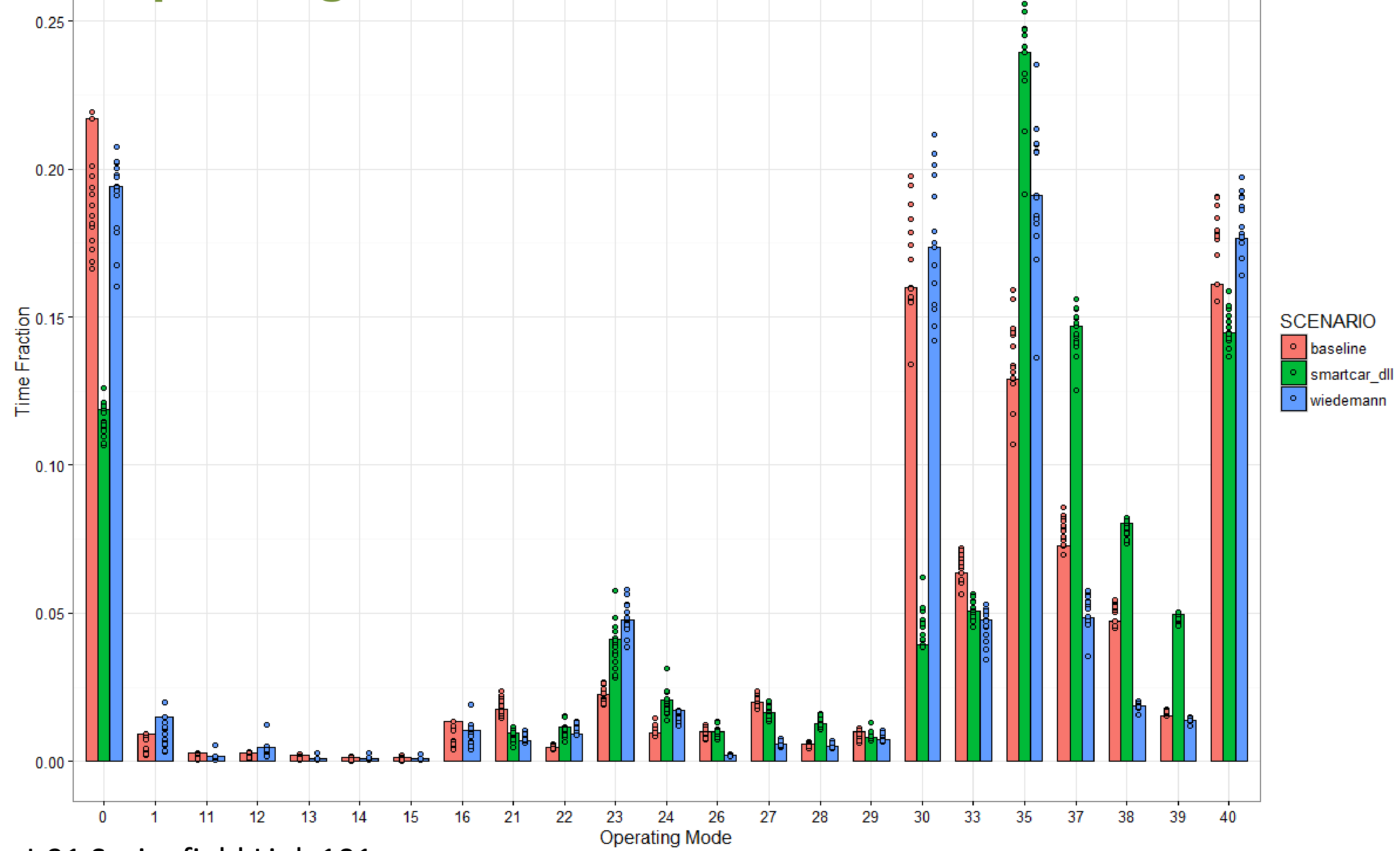
- Vehicle-specific power (VSP) and emissions are well correlated
- VSP is derived from instantaneous speed and acceleration along with other constants such as vehicle mass and aerodynamic drag
  - Microsimulations run at 10 Hz
- MOVES operating modes assigned according to VSP and speed bins
  - Separate op modes for braking (opModeID 0) and idling (opModeID 1)

**Operating Modes for Running Emissions**

| VSP Class (kW/tonne) | Speed Class (mph) | | |
|---|---|---|---|
| | 1-25 | 25-50 | 50 + |
| 30 + | 16 | 30 | 40 |
| 27-30 | | | |
| 24-27 | | 29 | 39 |
| 21-24 | | 28 | 38 |
| 18-21 | | | |
| 15-18 | | | 37 |
| 12-15 | | 27 | |
| 9-12 | 15 | 25 | |
| 6-9 | 14 | 24 | 35 |
| 3-6 | 13 | 23 | |
| 0-3 | 12 | 22 | 33 |
| < 0 | 11 | 21 | |

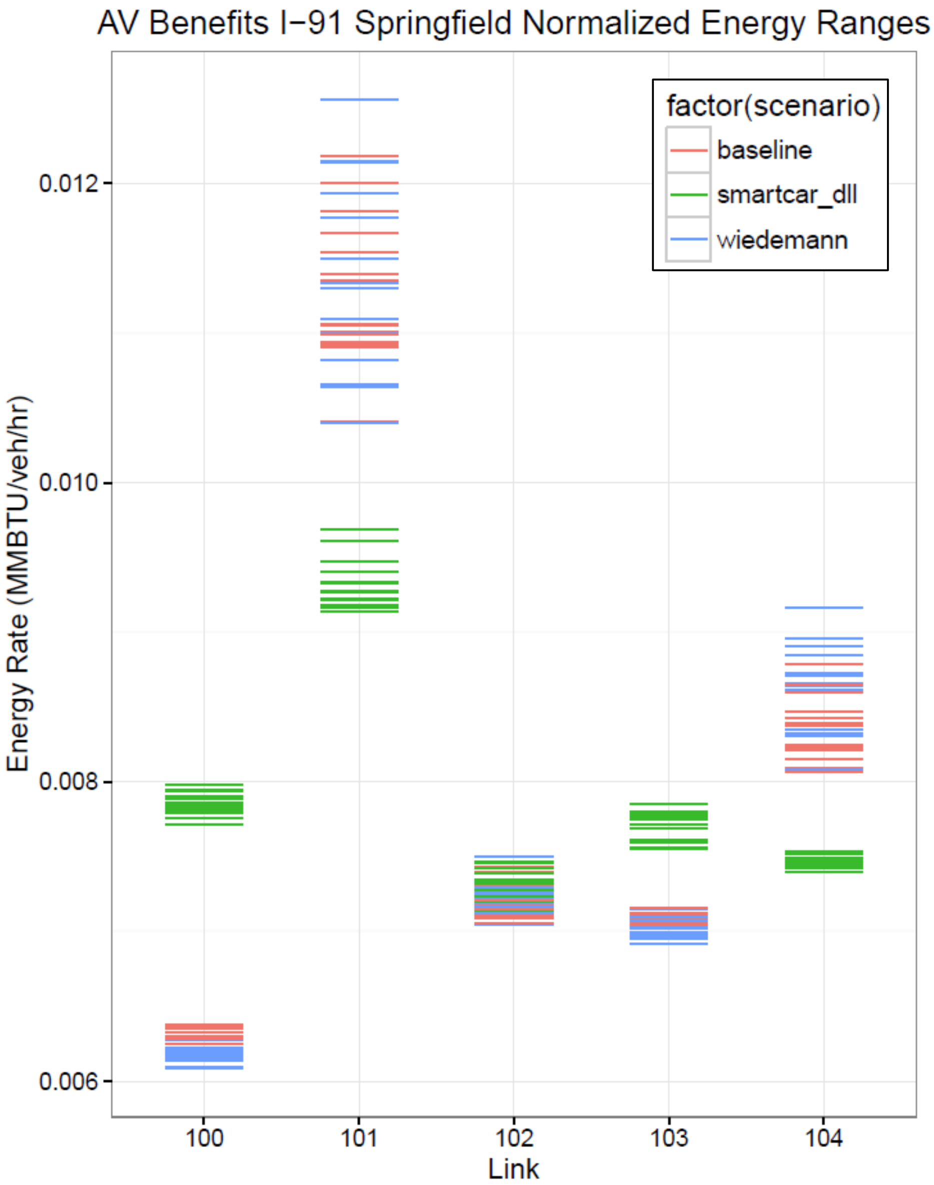
Beardsley (2011), MOVES Workshop

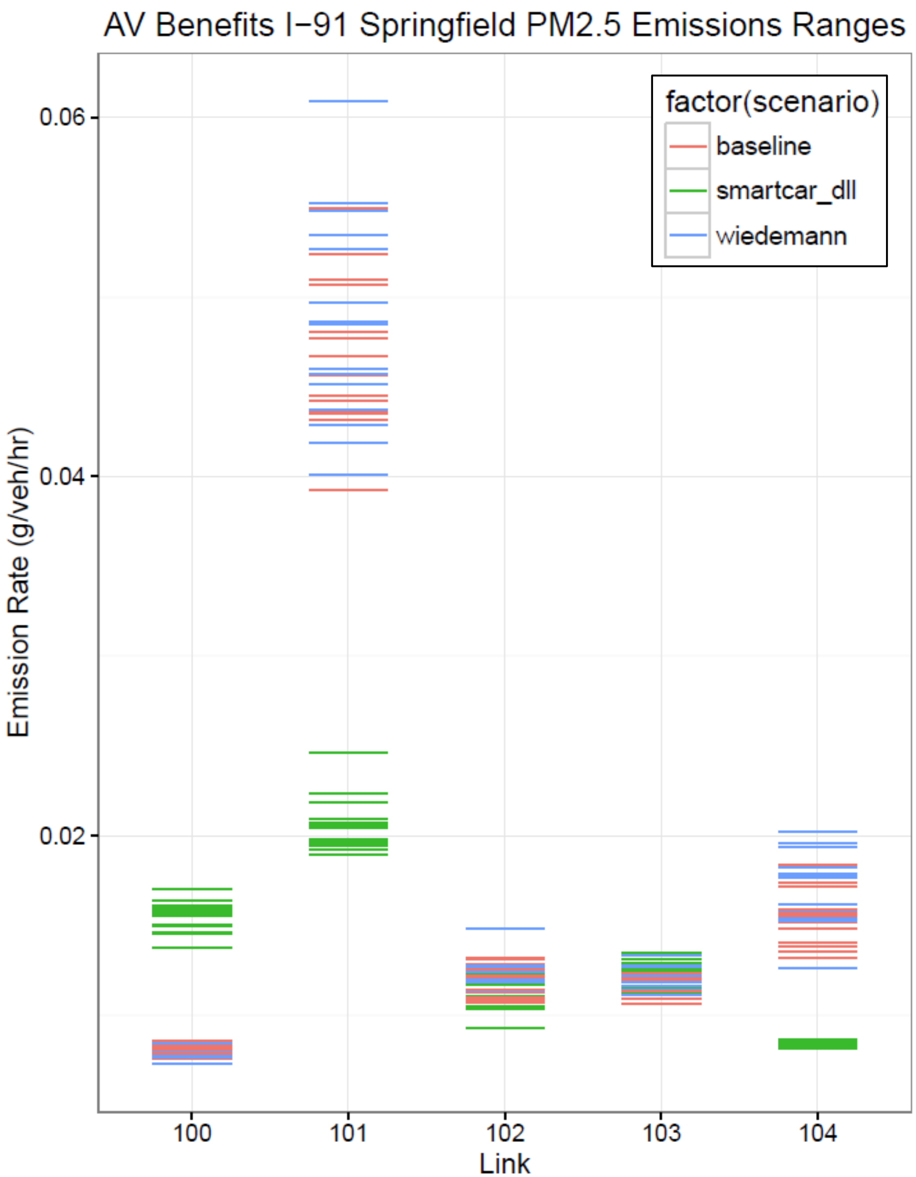
# Operating Mode Distributions




I-91 Springfield Link 101

# Emission and Energy Impacts

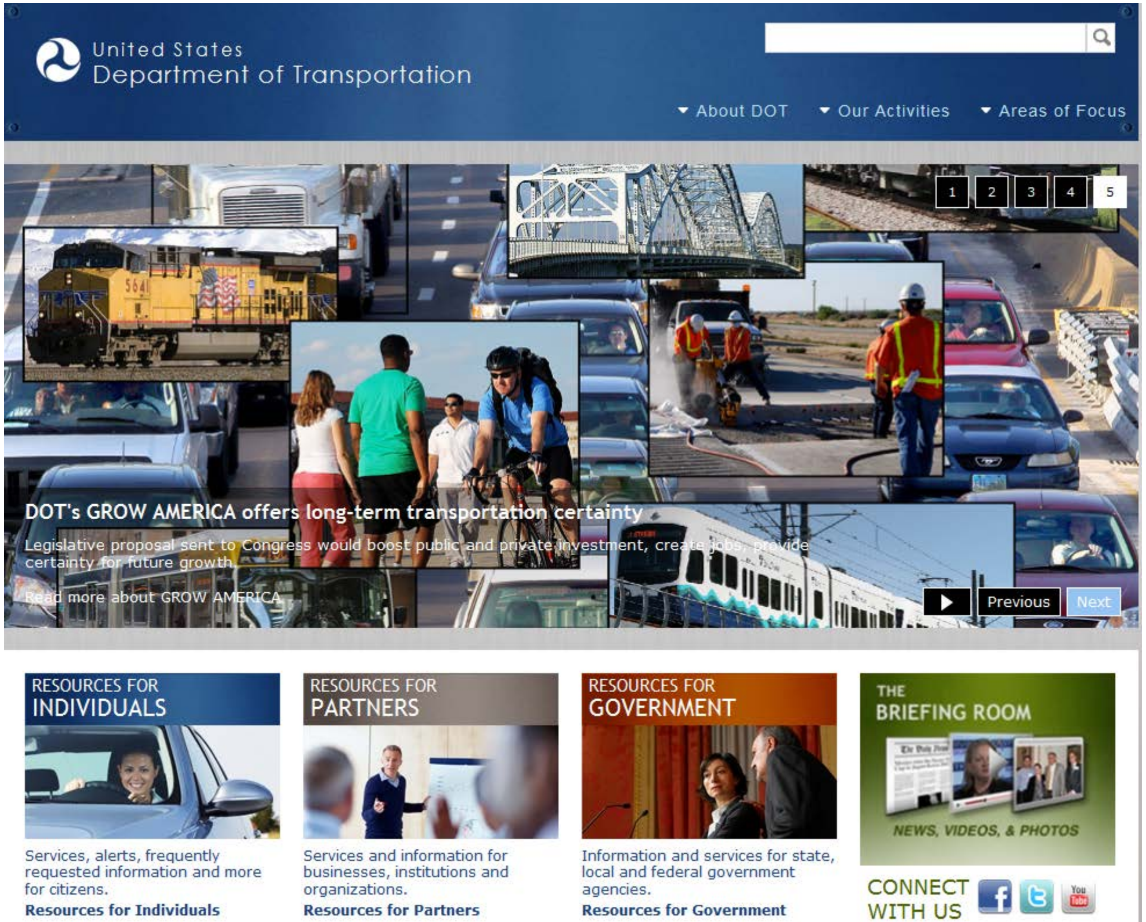


# Conclusions and Future Work

- Results
  - Automated vehicles generally show less braking, leave less headway, and have less fluctuations in speed and acceleration than baseline
  - Results are more pronounced for congested links
    - CACC has less of an effect on energy and emissions in freely flowing traffic
  - Traffic smoothing through setting the Wiedemann oscillations to zero does not have much benefit over the default car-following algorithm
  - DLL needs to be thoroughly tested and validated
- Next Steps
  - Vary traffic volumes to simulate higher densities of vehicles
    - Expect automation to matter more for heavily congested scenarios
  - Experiment with different penetrations of CACC-enabled vehicles
  - Investigate lane changing capabilities to accommodate merging and weaving

# For More Information




http://www.dot.gov/

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# Extra Slides

# Network Energy and Emissions Impacts