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Modeling the Energy Use of a Connected and Automated Transportation System

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Introduction and Purpose

Early research points to large potential impacts of connected and automated vehicles (CAVs) on transportation energy use – dramatic savings, increased use, or anything in between. [1,2] Due to a lack of suitable data and integrated modeling tools to explore these complex future systems, analyses to date have relied on simple combinations of isolated effects. This poster proposes a framework for modeling the potential energy implications from increasing penetration of CAV technologies and for assessing technology and policy options to steer them toward favorable energy outcomes.

Current CAV modeling challenges include estimating behavior change, understanding potential vehicle-to-vehicle interactions, and assessing traffic flow and vehicle use under different automation scenarios. To bridge these gaps and develop a picture of potential future automated systems, NREL is integrating existing modeling capabilities with additional tools and data inputs to create a more fully integrated CAV assessment toolkit.

Any effort to produce integrated modeling of such a complex and novel system will face challenges. These include selection of plausible inputs and handling of path dependence (what to model, in what order, and how to link disparate tools). When possible, data collection of related and early technology deployments should be used to validate each of the framework's modules.

Possible Applications

This first-of-a-kind toolkit will allow NREL and its research collaborators to address new and critical questions affecting the future of automation:

- What are the energy opportunities at the different levels of automation, from level 1 (function-specific automation) to level 4 (full self-driving automation)? [3]
- What factors most affect which path automation might take?
- What factors most affect the rate of CAV adoption and concurrent changes to the transportation system?
- Do we expect "tipping points" where system behavior changes qualitatively depending on CAV penetration and automation algorithms?
- How could system infrastructure deployment for vehicle connectivity influence CAVs in the transportation system?
- What other energy technologies may either benefit from or facilitate increased automation?

Loop through time for both equipped and non-equipped vehicles

Defining Inputs

CAV Capabilities

Why: Foundational technology cases for potential impact scenarios

Input assumptions: Technology/cost advancement rates

Iterative influence from increased production volumes

Infrastructure Characteristics

Why: Infrastructure coordination/ interaction impacts scenarios

Input assumptions: Road-side equipment (RSE) development and penetration rates

Iterative influence from inter-dependent penetration of vehicles and infrastructure and any travel behavior shifts

Vehicle Design

Why: Capture potential evolution of platform and powertrain as foundational technology cases

Input assumptions: Advanced powertrain/component cost curves

Iterative influences from consumer preference, driving demands

CAV penetration and relationship to safety-enabled lightweighting

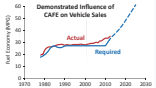
Standards/Regulations

EPA NHTSA

Why: Strong potential effects on adoption pace and use patterns from policies, including legality, insurance, liability, incentives, and treatment under regulations

Input assumptions: Mandates (e.g., DSRC), use restrictions, CAV-only zones, incentives/fees, VMT pricing, land use and parking regulation, treatment of CAVs under CAFE

Iterative influence from market penetration (e.g., phase-out of initial incentives, policy changes)



Modeling Interactions

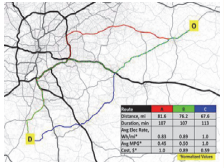
Behavior Modeling

Why: Capture how purchase and travel decisions may change in response to new technology availability

Supporting data/tool examples:

Vehicle uptake predictions using ADOPT, MA3T (consumer preference) or VICE, PReP, AFLEET (commercial net-present cost)

Travel behavior predictions using opinion surveys (asking about hypotheticals) and data collection (revealed behavior changes from car sharing, managed lanes, early prototype deployments)



Traffic Modeling

Why: Travel profile and car-following behavior differences

Supporting data/tool examples:

Baseline calibration data from surveys, TSDC

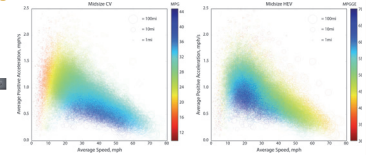
Trip generation analysis using tools such as VISUM

Traffic flow/drive profile analysis considering the combination of travel choices and interactions between equipped and non-equipped vehicles; use tools such as DRIVE, Vissim, POLARIS, Paramics

Powertrain Modeling

Why: Quantify energy use from different vehicle designs and operating conditions/profiles

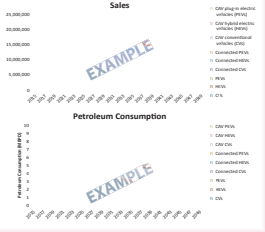
Supporting data/tool examples: Energy and emissions modeling from aggregate to detailed microsimulation estimates using tools such as MOVES, FASTSim, Autonomie



Estimating Effects

Fleet Makeup

What: Track fleet composition, including penetration of new technologies and turnover rate for baseline/legacy vehicles



Fleet Usage

What: Track use intensity through time for both CAVs and conventional vehicles in the fleet under various scenarios

Urban Form

What: Potential larger time-scale evolution of urban layout (iterative with vehicle/fleet characteristics)

Supporting tools: "Four-Step" and other travel-demand models, transportation land-use models, 4-D methods, and land-use scenario planning tools [4]

Scenario Energy Impacts/Examples

Possible paths:

Connectivity provides some fuel, safety, and mobility improvements, but overall changes are modest, with little change in vehicle size or ownership models

Full automation emerges with faster travel, more travel by underserved populations, and minor platform evolution (large vehicles remain with little powertrain type/size changes), leading to demand increases but few efficiency gains

CAV/PEV synergy leads to electrified fleet of automated taxis—with emphasis on improved operating cost/energy efficiency through changes like significant downsizing—leading to effects such as seamlessly linking personal and shared transportation systems and significantly changing the urban form

References

1 – An Analysis of Possible Energy Impacts of Automated Vehicle: http://link.springer.com/chapter/10.1007%2F978-3-319-05990-7_13#

2 – A First Order Estimate of Energy Impacts of Automated Vehicles in the United States: http://cta.ornl.gov/TRBenergy/trb_documents/2014_presentations/697_MacKenzie_.pdf

3 – NHTSA Preliminary Statement of Policy Concerning Automated Vehicles: http://www.nhtsa.gov/staticfiles/rulemaking/pdf/Automated_Vehicles_Policy.pdf (accessed July 8, 2014)

4 – Effects of the Built Environment on Transportation: Energy Use, Greenhouse Gas Emissions, and Other Factors: http://www.nrel.gov/docs/fy13osti/55634.pdf

Models and tools:

ADOPT: http://www.nrel.gov/vehiclesandfuels/data_resources.html
AFLEET: http://www.eere.energy.gov/cleancities/toolbox/pdfs/afleet_webinar.pdf
Autonomie: http://www.transportation.anl.gov/modeling_simulation/PSAT/autonomie.html
FASTSim: http://www.nrel.gov/vehiclesandfuels/vsa/fastsim.html
MA3T: http://cta.ornl.gov/ma3t
MOVES: http://www.epa.gov/otaq/models/moves
Paramics: http://www.paramics-online.com
POLARIS: https://www.tracc.anl.gov/index.php/polaris
PReP: http://www.afdc.energy.gov/tools
TSDC: http://www.nrel.gov/vehiclesandfuels/secure_transportation_data.html
VICE: http://www.afdc.energy.gov/uploads/publication/VICE_2_0_Jan_17_14.xlsx
Vissim: http://vision-traffic.ptvgroup.com/en-us/products/ptv-vissim
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