Potential Energy/Emissions Benefits from Connected Vehicles and Automation

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Matthew Barth
EE Professor, University of California-Riverside
Director, Center for Environmental Research and Technology

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Three regimes on how to reduce on-road energy and emissions through connected vehicles and automation.

Increased capacity of roadways through ITS reduces congestion.

Platooning reduces aerodynamic drag.

Connected Vehicles: providing better interaction between vehicles and between vehicles and infrastructure

- **Safety** Pilot Study

- **DMA** (Dynamic Mobility Applications)

- **AERIS** (Applications for the Environment and Real-Time Information Synthesis)
Eco-Signal Operations
- Uses connected vehicle technologies to decrease fuel consumption and decrease GHG and criteria air pollutant emissions by reducing idling, the number of stops, unnecessary accelerations and decelerations as well as improving traffic flow at signalized intersections.
- The Operational Scenario features the following applications:
  - Eco-Approach and Departure at Signalized Intersections
  - Eco-Traffic Signal Timing
  - Eco-Traffic Signal Priority

Eco-Lanes
- Dedicated freeway lanes — similar to HOV lanes — optimized for the environment that encourage use from vehicles operating in eco-friendly ways.
- Speed limits are optimized for the environment based on data collected from vehicles.
- Drivers may opt-in to eco-cooperative adaptive cruise control (ECACC) and vehicle platooning applications.
- Wireless (inductive) charging infrastructure embedded in the roadway allows electric vehicles to charge their batteries while the vehicle is moving at highway speeds.

Low Emissions Zones
- Geographically defined areas that seek to incentivize “green transportation choices” or restrict specific categories of high-polluting vehicles from entering the zone to improve the air quality within the geographic area.
- Incentives or fees may be based on the vehicle’s engine emissions standard or emissions data collected directly from the vehicle using V2I communications.
- Geo-fencing the boundaries of the Low Emissions Zone allows the possibility for these areas to be dynamic (e.g., pop-up for a Code Red Air Quality Day, special event, etc.)
Eco-Traveler Information

- Enables development of new, advanced traveler information applications through integrated, multisource, multimodal data.
- An open data/open source approach is intended to engage researchers and the private sector to spur innovation and environmental applications, including:
  - Dynamic Eco-Routing
  - Eco-Smart Parking
  - Multi-Modal Traveler Information (e.g., care sharing information, mode choice, etc.)

Eco-Integrated Corridor Management (E-ICM)

- Considers partnering among operators of various surface transportation agencies to treat travel corridors as an integrated asset, coordinating their operations simultaneously with a focus on decreasing fuel consumption, GHG emissions, and criteria air pollutant emissions.
- Includes a real-time data-fusion and decision support system that uses multisource, real-time data on arterials, freeways, and transit systems to determine which operational decisions have the greatest environmental benefit to the corridor.
Eco-Approach Scenario Diagram

Intersection of interest
Eco-Approach & Departure Experiment

Start (+190 m)

End (-120 m)

intersection

signal controller

Start (+190 m)

End (-120 m)
AERIS Demonstration at FHWA Turner Fairbank Highway Research Center

Traffic Signal Controller → Driver display advising driver

Vehicle OBD-II data → Vehicle computer performs velocity planning

SPaT processor → Road-side DSRC

wireless

On-board DSRC
Eco-Approach & Departure Example Run

- Cycle length of 60 sec (26 green, 4 yellow, 30 red)
- The vehicle approached the intersection when the light was red. The application guided the driver to slow down early and cruise pass the intersection when the light turned green, avoiding a full stop.  

*average fuel saved: 18%*
Eco-Approach and Departure Simulation Videos
Eco-Approach/Departure Modeling Conclusions

• Eco-approach & departure is an effective strategy, but has less impact with increased congestion
• In general, 5%- 10% fuel savings can be achieved with 100% penetration rate of technology for a typical arterial corridor
• Coordinated signal control by itself results in approximately 8% fuel/emissions reduction over uncoordinated
• Eco-approach and departure technology can provide an additional 4% - 5% improvement on top of a coordinated corridor
• Smaller penetration rate of technology still has a positive, larger network effect (non-equipped vehicles also have a slight benefit)
• Benefits sensitive to communications range but not delay
• Application can be accomplished with either DSRC or cellular communications
Cooperative Adaptive Cruise Control with Eco-Approach and Departure

• For isolated intersection:
  – Approach: platoon-based eco-approach
  – Departure: platoon discharges with minimum headway
Cooperative Adaptive Cruise Control example

Baseline: typical queuing

Arterial CACC Baseline
High Volume (800 vphpl)

CACC: ~18% less energy & emissions

Arterial CACC
High Volume (800 vphpl)
Take Away Points (1 of 2):

• Connected Vehicle strategies of improving safety and improving traffic performance (i.e. mobility) often reduce energy consumption and CO₂ emissions as a side benefit

• Dedicated CV strategies and systems can be designed to explicitly reduce energy consumption and CO₂ emissions: U.S. AERIS, Japan Energy ITS, EU EcoMove

• Each AERIS strategy can potentially reduce CO₂ emissions by approximately 5 – 15%; however with multiple strategies, greater savings may be achieved (ignoring induced demand)

• Partial automation provides better energy & emission results compared to human-machine interfaces
Take Away Points (2 of 2):

- With automation, system design **trade-offs** will exist between safety, mobility, and the environment (e.g., automated maneuvers)

- **Major barrier** to implementing eco-friendly connected vehicle and automation applications: low cost of fuel

- **Timing:** several AERIS applications can be implemented in the near-term, not requiring 100% penetration to realize some environmental benefits

- **Potential induced demand effects:** Connected vehicle and automation applications may need to also consider travel demand management techniques
Research Team

- University of California-Riverside:
  - Matthew Barth (principal investigator)
  - Kanok Boriboonsomsin (research faculty)
  - Guoyuan Wu (research faculty)
  - Haitao Xia, David Kari (graduate students)

- Other Research Team Members:
  - Balaji Yelchuru
  - Sean Fitzgerel
  - Sudeeksha Murari
  - JD Schneeberger

- US DOT
  - Marcia Pincus
  - Bob Ferlis
  - Peter Huang
  - + many others
Different Intersection Management Systems

stop signs

traffic light

Intersection reservation system with connected vehicles

Source: David Kari, UCR, 2014