Connected Vehicle Applications Targeted for Environmental Improvements

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Approaches to Minimize Energy and Emissions Impacts of Transportation:

• **Build cleaner, more efficient vehicles:**
  • make vehicles lighter (and smaller) while maintaining safety
  • improve powertrain efficiency
  • develop alternative technologies (e.g., hybrids, fuel-cell, electric vehicles)

• **Develop and use alternative fuels:**
  • Bio and synthetic fuels (cellulosic ethanol, biodiesel)
  • electricity

• **Decrease the total amount of driving:** **VMT reduction methods**
  • Better land use/transportation planning
  • Travel demand management

• **Improve transportation system efficiency**
  • Intelligent Transportation System (ITS) technologies
  • Connected Vehicles → Vehicle Automation
Key ITS Research Areas with Energy/Emissions Impacts

Advanced Vehicle Control and Safety Systems: *Vehicles*
- Longitudinal and Lateral Collision Avoidance
- Intersection Collision Avoidance
- Adaptive Cruise Control, Intelligent Speed Adaptation
- Automated Vehicles and Roadway Systems

Advanced Transportation Management Systems: *Systems*
- Traffic Monitoring and Management
- Corridor Management
- Incident Management
- Demand Management and Operations

Advanced Transportation Information Systems: *Behavior*
- Route Guidance
- En-Route Driver Information
- Traveler Service Information → connection to Transit
- Electronic Payment Services → variable pricing
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)

Objectives:

- Identify connected vehicle applications that could provide environmental impact reduction benefits via reduced fuel use, more efficient vehicles, and reduced emissions.

- Facilitate and incentivize “green choices” by transportation service consumers (i.e., system users, system operators, policy decision makers, etc.).

- Identify vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and vehicle-to-grid (V2G) data (and other) exchanges via wireless technologies of various types.

- Model and analyze connected vehicle applications to estimate the potential environmental impact reduction benefits.

- Develop a prototype for one of the applications to test its efficacy and usefulness.
The AERIS Approach

**Concept Exploration**
Examine the State-of-the-Practice and explore ideas for AERIS Operational Scenarios

**Development of Concepts of Operations for Operational Scenarios**
Identify high-level user needs and desired capabilities for each AERIS scenario in terms that all project stakeholders can understand

**Conduct Preliminary Cost Benefit Analysis**
Perform a preliminary cost benefit analysis to identify high priority applications and refine/refocus research

**Prototype Application**
Develop a prototype for one of the applications to test its efficacy and usefulness.

**Modeling and Analysis**
Model, analyze, and evaluate candidate strategies, scenarios and applications that make sense for further development, evaluation and research

**Where we are today**
5-year Program
3 Years into Research
AERIS Program Status

- Foundational Research – Complete
  - Broad Agency Announcement (BAA) Projects
  - State-of-the-Practice Reports (applications, modeling, and eval techniques)
- Initial Benefit Cost Analysis – Complete
  - Identified key assumptions for evaluation
  - Benefit-cost results were used to prioritize applications for additional analysis
- Concept of Operations Documents – Complete
  - Eco-Signal Operations; Eco-Lanes; Low Emissions Zones
- Modeling and Evaluation – Ongoing
- US/EU Sustainability Working Group (SWG) – Ongoing
  - Developing White Papers that compare and contrast various aspects of US and EU connected vehicle research
  - Demonstration of a jointly developed application at the 2015 ITS World Congress in Bordeaux, France
System Activities:

- advanced signal control
- I2V-based communications
- I2V & V2I communications
- network equilibration

Arterial Data Environments

Phase 1: Accelerating
Phase 2: Cruising
Phase 3: Decelerating
Phase 4: Idling
Phase 5: Accelerating

DSRC Range (r)

Vehicle 1
Vehicle 2
Vehicle 3
Vehicles 2 & 3

Analysis boundary
System Activities: ECO-Signal Operation

Time-distance diagram of disorganized traffic through corridor

References:


Time-distance diagram of organized traffic through corridor using SPaT
Eco-Approach & Departure Experiment

Intersection

Start (+190 m)

End (-120 m)

Signal Controller
Human-Machine Interface

- Speedometer
- SPaT
- tachometer
- Advisory speed
- Real-time MPG
- Vehicle location indicator
- Distance to intersection
- Intersection location indicator
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.
System Activities:

- intelligent speed adaptation
- speed harmonization
- variable Speed Limits
- dynamic eco-driving
- platooning
- cooperative cruise control
Connected Eco-Driving Experiment

<table>
<thead>
<tr>
<th>Energy/Emissions</th>
<th>Non Eco-Driving</th>
<th>Eco-Driving</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel (g)</td>
<td>1766</td>
<td>1534</td>
<td>-13%</td>
</tr>
<tr>
<td>CO2 (g)</td>
<td>5439</td>
<td>4781</td>
<td>-12%</td>
</tr>
<tr>
<td>CO (g)</td>
<td>97.01</td>
<td>50.47</td>
<td>-48%</td>
</tr>
<tr>
<td>HC (g)</td>
<td>3.20</td>
<td>1.90</td>
<td>-41%</td>
</tr>
<tr>
<td>NOx (g)</td>
<td>6.28</td>
<td>3.97</td>
<td>-37%</td>
</tr>
<tr>
<td>Travel time (min)</td>
<td>38.9</td>
<td>41.2</td>
<td>+6%</td>
</tr>
</tbody>
</table>

Vehicle automation could provide even better results.

Behavior Activities:

Focus on Behavior:
- eco-routing
- eco-driving
- smart parking
AERIS Preliminary Modeling Results

Eco-Approach and Departure at Signalized Intersections:

- In general, **5% - 10% fuel savings can be achieved for individual vehicles**
- Effectiveness is dependent on roadway conditions; **less effective with increased congestion**
- A small penetration rate has a positive network effect, where **non-equipped vehicles also receive a slight benefit**
- For a corridor that has already been optimized for mobility (e.g., coordinated traffic signals), the application only provides a slight improvement (1% - 3%) to mainline traffic flow
- The application is very **sensitive to communication range, but not communication delay**

Eco-Traffic Signal Timing:

- **At low connected vehicle penetration rates, there is not enough data to support optimization.** Modeling results indicated minimal or negative benefits compared to the baseline.
- **As connected vehicle penetration rates increase, modeling results indicated significant reductions in emissions and delay** compared to the baseline. Benefits appear to:
  - Increase significantly from 20% to 50% connected vehicle penetration levels
  - Remain consistent between 50% and 80% connected vehicle penetration levels
  - Increase significantly from 80% to 100% connected vehicle penetration levels
Take Away Points:

• ITS goals and strategies of improving safety and improving traffic performance (i.e. mobility) often reduce energy consumption and CO$_2$ emissions as a side benefit.

• Dedicated ITS strategies and systems can be designed to explicitly reduce energy consumption and CO$_2$ emissions: U.S. AERIS, Japan Energy ITS, EU EcoMove.

• Each ITS strategy can potentially reduce CO$_2$ emissions by approximately 5 – 15%; however with multiple strategies, greater savings can be achieved (ignoring induced demand).
Challenges:

• Better quantification tools and data are needed to quantify environmental impacts

• Environmental ITS research not only includes technology research but also *behavioral* research

• Trade-offs will exist between safety and ECO-ITS

• ITS applications need to consider travel demand management techniques to address potential induced demand effects