Applications for the Environment: Real-Time Information Synthesis (AERIS)

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Transportation’s Impact on the Environment

Surface transportation has a significant impact on the environment:

- Transport sector in the US accounts for 27% of GHG emissions and 70% of US petroleum consumption. Light duty vehicles and heavy trucks are the greatest fuel users in the transport sector.
- Surface vehicles represent almost 84% of the transport sector GHG in the US.

Strategies for Reducing Surface Transportation-Related Emissions

**Strategy #1** Vehicle Technology
• Improve the energy efficiency of the vehicle fleet by implementing more advanced technologies including engine performance optimization and automation

**Strategy #2** Fuel Technology
• Reduce the carbon content of fuels through the use of alternative fuels (for instance, natural gas, biofuels, and hydrogen)

**Strategy #3** Travel Activity
• Reduce the number of miles traveled by vehicles, or shift those miles to more efficient modes of transportation

**Strategy #4** Vehicle and System Operations
• Improve the efficiency of the transportation network so that a larger share of vehicle operations occur in favorable conditions, with respect to speed and smoothness of traffic flow, resulting in more fuel efficient vehicle operations
AERIS Research Objectives

- **Vision** – Cleaner Air through Smarter Transportation

- **Objectives** – Investigate whether it is possible and feasible to:
  
  - Identify connected vehicle applications that could provide environmental impact reduction benefits via reduced fuel use, improved vehicle efficiency, and emissions reductions.
  
  - 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

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

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

**Where we are today**

5-year Program
3 Years into Research

U.S. Department of Transportation
AERIS Program Status

- Foundational Research – Complete
  - Broad Agency Announcement (BAA) Projects
  - State-of-the-Practice Reports (applications, modeling, and evaluation techniques)

- Initial Benefit Cost Analysis – Complete
  - Identified key assumptions for evaluation
  - Benefit and 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
  - Eco-Signal Operations Modeling – preliminary results expected in October 2013

- US/EU Sustainability Working Group (SWG) – Ongoing
  - Developing White Papers that compare and contrast various aspects of US and EU connected vehicle research
  - Possible demonstration of a jointly developed application at the 2015 ITS World Congress in Bordeaux, France
Eco-Signal Operations

OPERATIONAL SCENARIO DESCRIPTION

- 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.

POTENTIAL BENEFITS

- A number of traffic signal coordination projects have documented emissions savings.
  - Syracuse, New York | Emissions reductions ranging from 9 to 13%.
  - Los Angeles, California | Emissions reductions of 14% and a reduction of fuel by 13%.
- Eco-Approach and Departure at Signalized Intersections
  - Initial modeling results for the El Camino Real corridor resulted in 5% to 10% fuel savings with 100% penetration rate, without significantly increasing travel time. On a well coordinated corridor, this saving is reduced down to 1% to 4%.

OPERATIONAL SCENARIO VISUALIZATION
## Eco-Lanes

### Operational Scenario Description

- Dedicated freeway lanes – similar to HOV lanes – optimized for the environment that encourage use from vehicles operating in eco-friendly ways.
- Variable 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.

### Potential Benefits

- Variable Speed Limit (VSL) systems reduce congestion, provide more reliable journey times, reduce the frequency of accidents, reduce carbon emissions, and reduce driver stress.
- University of Texas at Austin research found that reducing speed limits on a freeway from 65 mph to 55 mph on a “Code Red Air Quality Day” resulted in a 17% reduction in NOx over a 24 hour period.
- The Safe Road Trains for the Environment (SARTRE) Project in Europe estimates that vehicle platooning has the potential to reduce CO2 emissions by 20%.

### Operational Scenario Visualization

- Eco-Lane equipped with wireless inductive charging
- Smart Grid
- Eco-Cooperative Adaptive Cruise Control (ECACC) and Vehicle Platooning

Source: Noblis, July 2013
Low Emissions Zones

OPERATIONAL SCENARIO DESCRIPTION

- 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 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 responsive to specific traffic and environmental conditions (e.g., pop-up for a Code Red Air Quality Day, special event, etc.).

POTENTIAL BENEFITS

- The London Low Emissions Zone “aims to reduce traffic pollution by deterring the most polluting diesel-engine lorries, buses, coaches, minibuses, and large vans from driving within the city.”
- According to a 2006 study, concentrations of small particles from traffic sources were expected to decrease across London by 4.3 percent in 2008 and 8.0 percent in 2010 due to the Low Emissions Zone, and NOx was expected to decrease by 3.2 percent in 2008 and 4.1 percent in 2010.
Eco-Traveler Information

OPERATIONAL SCENARIO DESCRIPTION

• 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:
  - Responsive Eco-Routing
  - Alternative Fuel Vehicle Charging/Fueling Information
  - Eco-Smart Parking
  - Multi-Modal Traveler Information (e.g., fuel use/$ saved/emissions reduced smartphone apps, car sharing information, mode choice, etc.)

POTENTIAL BENEFITS

• A study titled “Green Routing Buffalo Final Report” found that green routing could yield an average fuel consumption benefit of 16.7%.
• The benefits of multi-modal traveler information include reducing driving and VMTs due to increased carpooling, car sharing, public transportation, and planning ahead to combine trips.
• Estimates show that one person using mass transit for an entire year, instead of driving to work, can keep an average of 62.5 pounds of carbon monoxide (CO) from being emitted. This is equivalent to 28,350 grams of CO.

OPERATIONAL SCENARIO VISUALIZATION

Source: Graphic Adapted from Concept of Operations: DCM, August 2010
Eco-Integrated Corridor Management

ICM modeling for I-880 in Oakland, CA show:
• HOT lane and highway traveler information were the most effective strategies.
• Highway traveler information produced a large benefit, especially in the case of unexpected events such as a major incident.
• Transit traveler information produced less benefit than highway traveler information.
• In high demand conditions, arterial signal coordination produced a benefit-to-cost ratio that ranged from 12:1 to 20:1.
• Combining multiple ICM strategies produced a benefit-to-cost ratio that ranged from 7:1 to 25:1.

OPERATIONAL SCENARIO DESCRIPTION

• 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.

POTENTIAL BENEFITS

OPERATIONAL SCENARIO VISUALIZATION

Source: USDOT
# Synergies Between AERIS and DMA Applications

## AERIS Applications (select applications)

- **Eco-Signal Operations**
  - Eco-Approach and Departure at Signalized Intersections
  - Eco-Traffic Signal Timing
  - Eco-Transit Signal Priority
  - Eco-Freight Signal Priority
  - Wireless Inductive Charging

- **Eco-Lanes**
  - Eco-Lanes Management
  - Eco-Cooperative Adaptive Cruise Control
  - Eco-Speed Harmonization
  - Eco-Ramp Metering
  - Wireless Inductive Charging

- **Low Emissions Zones**
  - Low Emissions Zone Management

- **Eco-Traveler Information**
  - Eco-Smart Parking
  - AFV Charging/Fueling Information
  - Multi-Modal Traveler Information
  - Dynamic Eco-Routing

- **Eco-Integrated Corridor Management**

## DMA Applications (select applications)

- **Multi-Modal Intelligent Traffic Signal System**
  - Connected Eco-Driving (ECO) – *DMA Support, Not Funded*
  - Intelligent Traffic Signal System (I-SIG)
  - Transit Signal Priority (TSP)
  - Freight Signal Priority (FSP) – *DMA Support, Not Funded*
  - N/A

- **Intelligent Network Flow Optimization (INFLO)**
  - N/A
  - Cooperative Adaptive Cruise Control (CACC)
  - Dynamic Speed Harmonization (SPD-HARM)
  - Ramp Metering (RAMP) – *DMA Support, Not Funded*
  - N/A

- **N/A**
  - N/A (potential synergies with VMT and ETC applications)

- **Enable ATIS**
  - Smart Park & Ride (S-PARK) – *DMA Support, Not Funded*
  - N/A
  - Multi-Modal Traveler Information (ATIS) – *DMA Support, Not Funded*
  - Dynamic Routing of Vehicles (DRG)

- **Integrated Corridor Management (ICM)**
The AERIS Program is researching connected vehicle applications that seek to achieve ‘**maximum environmental benefits**’

- In general, *improving mobility results in environmental benefits* – but can we achieve greater environmental benefits by optimizing for the environment rather than only for mobility?
  - **Situations may exist where mobility and environmental benefits diverge**
    - Eco-speed limits, freight signal priority, eco-routing, and low emissions zones

For similar DMA and AERIS applications, **the vast majority of functionality/requirements are the same; however AERIS applications consider:**

- *Environmental data collected from vehicles* (e.g., fuel consumption or emissions data)
- *Algorithms that optimize the vehicle or transportation network for the environment* by considering environmental measures of effectiveness (MOEs) instead of mobility MOEs
- Traveler information/feedback that *incentivizes “green choices”*
- *Alternative fuel vehicle needs* (e.g., information about charging/fueling stations, parking for AFVs, engine start/stop technologies, and wireless inductive charging)
Preliminary Modeling Results and Key Findings

**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 relatively small penetration rate of this application 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 eco-approach and departure technology only provides a slight improvement (1% - 3%) to mainline traffic flow.
- The application is very sensitive to communication range, but not to communication delay.

*Source: Noblis, July 2013*
Preliminary Modeling Results and Key Findings

Eco-Traffic Signal Timing:

- The application optimizes traffic signal timing plans (e.g., cycle lengths, splits, and offsets) along a signalized corridor for the purpose of reducing emissions.
- AERIS models integrate a traffic simulation model (Paramics), environmental model (MOVES), and a genetic algorithm.
- Initial modeling results indicate:
  - At low connected vehicle penetration rates (e.g., 20% of vehicles equipped), there is not enough data provided to the genetic algorithm to support optimization. Modeling results indicated minimal or negative environmental 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 rates
    - Remain consistent between 50% and 80% connected vehicle penetration rates
    - Increase significantly from 80% to 100% connected vehicle penetration rates
  - When optimizing to reduce Carbon Dioxide (CO₂) emissions, hydrocarbons (HC), Nitrogen Oxides (NOₓ), fuel consumption, and delay were also reduced.
- Additional analysis is being conducted to compare signal timing plans optimized for the environment with signal timing plans optimized for mobility.
Moving Forward

- **Upcoming AERIS Webinars: 3rd Annual Fall/Winter AERIS Webinar Series**
  - Webinar #1: Incorporation of Stakeholder Feedback into the AERIS Program (October 23, 2013)
  - Webinar #2: Preliminary Eco-Approach and Departure at Signalized Intersections Modeling Results (November 20, 2013)
  - Webinar #3: Preliminary Eco-Traffic Signal Timing Modeling Results (January 29, 2013)
  - Webinar #4: Preliminary Eco-Transit Signal Priority (for Transit and Freight) and Connected Eco-Driving Modeling Results (February 2014)
  - Webinar #5: A Comparison of US and EU Connected Vehicle Environmental Research Activities (March 2014)
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