UNITED STATES
DEPARTMENT OF TRANSPORTATION

Eco-Lanes

Concept of Operations

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

Adapted from the Eco-Lanes Concept of Operations Document

AERIS

AERIS Operational Scenarios

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.

ECO-LANES

Dedicated freeway lanes – similar to HOV lanes – optimized for the environment that encourage use from vehicles operating in eco-friendly ways. The lanes may support variable speed limits, eco-cooperative adaptive cruise control (ECACC) and vehicle platooning applications, and wireless inductive/resonance charging infrastructure embedded in the roadway.

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. Geo-fencing the boundaries allows the possibility for these areas to be responsive to real-time traffic and environmental conditions.

ECO-TRAVELER INFORMATION

Applications that enable development of new, advanced traveler information applications through integrated, multisource, multimodal data. An open data/open source approach is intended to spur innovation and environmental traveler information applications. Eco-Traveler Information applications include applications that assist users with finding charging stations for alternative fuel vehicles, parking applications, and eco-routing applications.

ECO-INTEGRATED CORRIDOR MANAGEMENT

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 and emissions.

Eco-Lanes

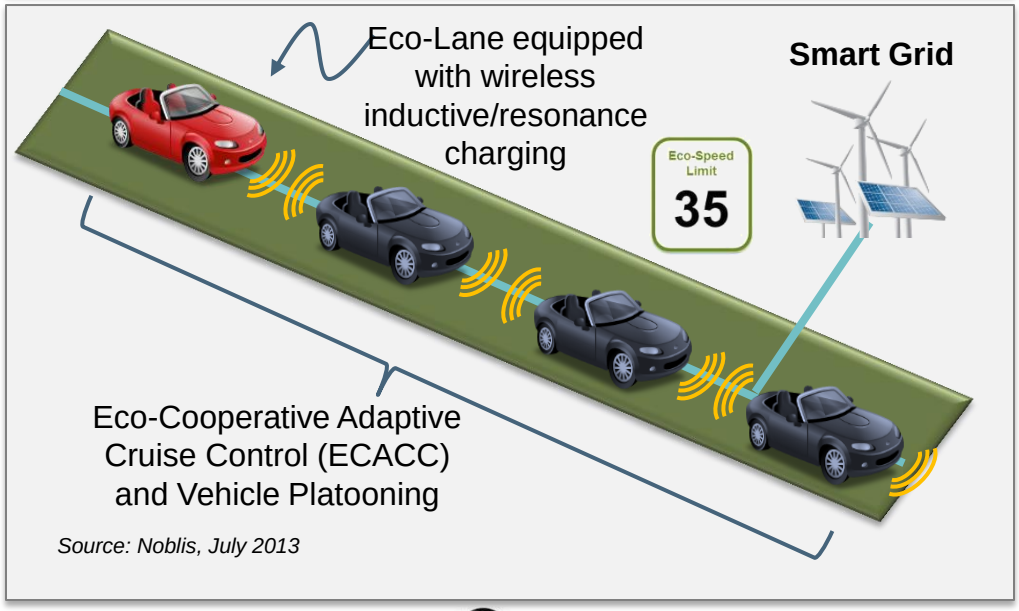
Operational Scenario Description

- 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/Resonance 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 NO_x over a 24 hour period.[1]
- The Safe Road Trains for the Environment (SARTRE) demonstrations indicated up to a 16 percent reduction in fuel consumption for the following vehicles and up to an 8 percent reduction for the lead vehicle.[2]

Operational Scenario Visualization



Source: Noblis, July 2013

Eco-Lanes Applications

Application Description

Eco-Lanes Management

This application establishes parameters and defines or geo-fences the eco-lanes boundaries. Eco-lanes parameters may include the types of vehicles allowed in the eco-lanes, emissions parameters for entering the eco-lanes, the number of lanes, and the start and end of the eco-lanes. The application also conveys pre-trip and en route traveler information about eco-lanes to travelers, including information about parameters for vehicles to enter the eco-lanes, current and predicted traffic conditions, and geographic boundaries of the eco-lanes.

Eco-Speed Harmonization

This application determines eco-speed limits based on traffic conditions, weather information, and GHG and criteria pollutant information. The purpose of speed harmonization is to change speed limits on links that approach areas of traffic congestion, bottlenecks, incidents, special events, and other conditions that affect flow. Speed harmonization assists in maintaining flow, reducing unnecessary stops and starts, and maintaining consistent speeds, thus reducing fuel consumption, GHG emissions, and other emissions on the roadway. Eco-speed limits can be broadcast by roadside equipment (RSE) units and received by on-board equipment (OBE) units or displayed on VSL signs located along the roadway. This application is similar to current VSL applications, although the speed recommendations seek to minimize emissions and fuel consumption along the roadway.

Eco-Cooperative Adaptive Cruise Control

The Eco-Cooperative Adaptive Cruise Control application is an extension to the adaptive cruise control (ACC) concept. Eco-Cooperative Adaptive Cruise Control includes longitudinal automated vehicle control while considering eco-driving strategies. Expanding on existing ACC systems, which use radar and LIDAR measurements to identify the location of the preceding vehicle, connected vehicle technologies can be used to collect the preceding vehicle's speed, acceleration, and location and feed these data into the vehicle's ACC. These data are transmitted from the lead vehicle to the following vehicle. This application allows following vehicles to use CACC aimed at relieving a driver from manually adjusting his or her speed to maintain a constant speed and a safe time gap from the lead vehicle. The Eco-Cooperative Adaptive Cruise Control application incorporates other information, such as road grade, roadway geometry, and road weather information, to determine the most environmentally efficient trajectory for the following vehicle. In the long term, the application considers vehicle platooning, where two or more vehicles travel with small gaps, reducing aerodynamic drag.

Eco-Lanes Applications

Application Description

Eco-Ramp Metering

The Eco-Ramp Metering application determines the most environmentally efficient operation of traffic signals at freeway on-ramps to manage the rate of entering vehicles. This application collects traffic and environmental data to allow on-ramp merge operations that minimize overall emissions, including traffic and environmental conditions on the ramp and on the freeway upstream and downstream of the ramp. Using this information, the application determines a timing plan for the ramp meter based on current and predicted traffic and environmental conditions. The objective for this application is to produce timing plans that reduce overall emissions, including reducing emissions from bottlenecks forming on the freeway as well as emissions from vehicles on the ramp.

Connected Eco-Driving

The Connected Eco-Driving application provides customized real-time driving advice to drivers, allowing them to adjust behaviors to save fuel and reduce emissions. This advice includes recommended driving speeds, optimal acceleration and deceleration profiles based on prevailing traffic conditions, and more local interactions with nearby vehicles. Finally, the application may also consider vehicle-assisted strategies, where the vehicle automatically implements the eco-driving strategy (i.e., change gears, switch power sources, or use start-stop capabilities to turn off the vehicle's engine while it is sitting in congestion).

Wireless Inductive/Resonance Charging

Wireless inductive/resonance charging includes infrastructure deployed along the roadway that uses magnetic fields to wirelessly transmit large electric currents between metal coils placed several feet apart. This infrastructure enables charging of electric vehicles including cars, trucks, and buses. Roadside charging infrastructure supports charging vehicles while moving.

Eco-Traveler Information Applications

Applications included in the Eco-Traveler Information Operational Scenario apply. Traveler Information specific to Eco-Lanes may include: parameters for the Eco-Lanes, travel time or fuel savings comparison between the Eco-Lanes and general purpose lanes, incident information, availability of wireless inductive/resonance charging in the Eco-Lanes, vehicle platooning rules and parameters, transit options, and parking information.

Goals and Objectives

Goal #1: Reduce Environmental Impacts	Goal #2: Support "Green Transportation Decisions" by Travelers and Operating Entities	Goal #3: Enhance Mobility of the Transportation System *(secondary goal)*	Goal #4: Improve the Safety of the Transportation System *(secondary goal)*

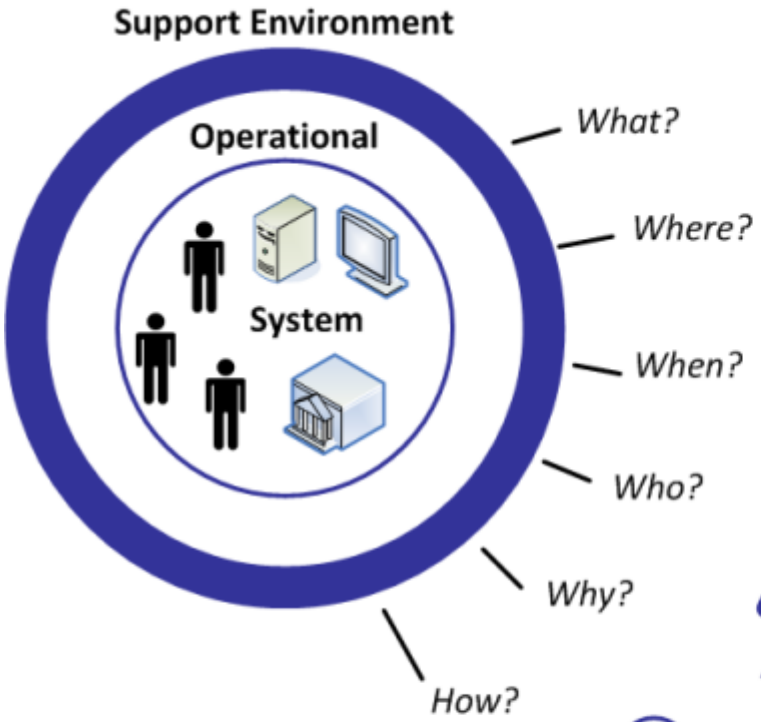
• **Reduce Emissions from Surface Transportation Vehicles**
  • Reduce CO_2, CO, NO_X, SO_2, PM_{10}, $PM_{2.5}$, VOCs
 	
• **Reduce Energy Consumption Associated with Surface Transportation Vehicles**
  • Reduce excess fuel
  • Reduce energy consumption
	• **Increase Modal Shifts to Transit, Carpooling, and Vanpooling**
	
	• **Increase Purchases of Alternative Fuel Vehicles (AFVs)**
	
	• **Increase Vehicle Miles Traveled (VMT) of Alternative Fuel Vehicles**
	
	• **Increase Eco-Driving Awareness and Practice**
	
	• **Reduce Range Anxiety for Drivers of Electric Vehicles**
	
	• **Increase the Range of Electric Vehicles**
		• **Improve the Efficiency of the Transportation System**
		  • Reduce delay
		  • Improve the efficiency of the freeway (e.g., LOS)
		
		• **Improve Transit Operating Efficiency**
		
		• **Improve Freight Operating Efficiency**
			• **Reduce Crashes, Injuries, and Fatalities**
			  • Reduce total number of crashes on the freeway
			  • Reduce the number of injuries on the freeway
			  • Reduce the number of fatalities on the freeway

Concept of Operations (ConOps)

- Provides an operational description of “how” the Operational Scenarios may operate
- Builds consensus among AERIS user groups and stakeholders concerning needs and expectations of:
  - USDOT
  - State and Local Departments of Transportation (DOTs)
  - Regional Planning Organizations
  - The Automotive Industry
  - ITS Developers, Integrators, and Researchers
- Serves as a guideline moving forward with research and development of AERIS applications

AERIS Concepts of Operations are intended to be a blueprint describing the Operational Scenarios so all stakeholders can understand how they may work

Conceptual Representation of a ConOps



Note: Graphic adapted from ANSI/AIAA's "Guide for the Preparation of Operational Concept Documents" ANSI/AIAA G-043-1992)

AERIS Concept of Operations

- AERIS Concept of Operations documents are intended to convey "transformational ideas" that will be modeled to show the potential environmental benefits that can be achieved through connected vehicle applications

- AERIS Concept of Operations are "generalized" and not specific to:
  - Geographic area
  - Operating entity (e.g., state or local DOT)
  - Existing systems that may be in place
  - Operating procedures
  - Political environment

Defining the System

ECO-LANES SYSTEM

Eco-Lanes System

- Most likely resides in a Traffic Management Center
- Developed by state and local DOTs and ITS developers
- Integrated with existing ITS systems (i.e., ATMS operating platforms)
- Collect V2I messages (e.g., probe messages and environmental messages)
- Processes connected vehicle and 'conventional' data
- Disseminates traveler information messages
- Implements operational strategies (e.g., ramp meter timing plans, eco-speed limits, etc.)

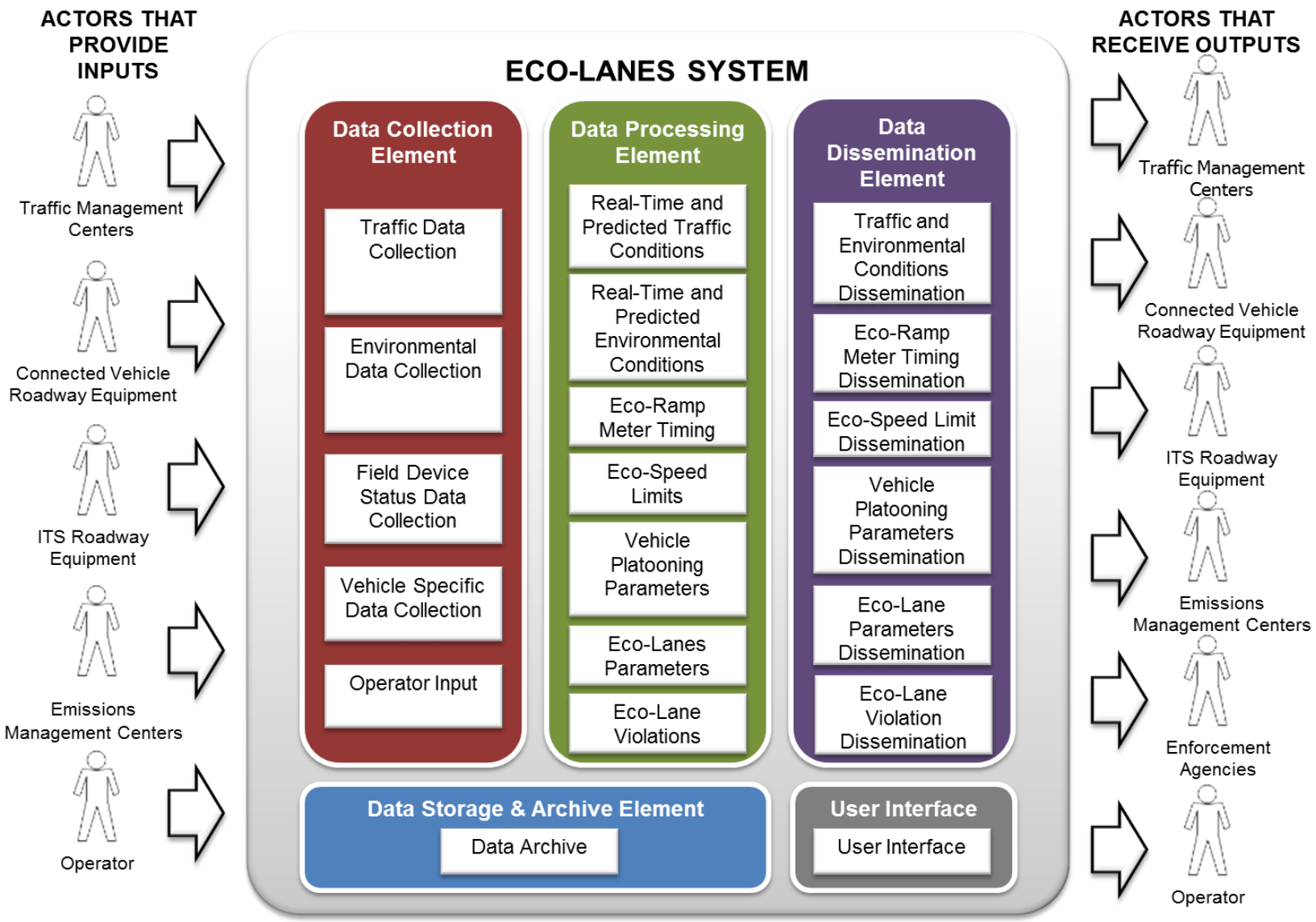
IN-VEHICLE SYSTEM

In-Vehicle System

- Resides in the vehicle
- Developed by automobile OEMs or aftermarket device vendors.
- Collects vehicle diagnostics data, V2V, and V2I messages
- Provides V2V messages to other vehicles
- Provides V2I messages to Connected Vehicle Roadway Equipment
- Implements eco-driving strategies (e.g. CACC, vehicle platooning, etc.)

Eco-Lanes System

- The Eco-Lanes System is a computerized transportation operations system that:
  - Gathers traffic and environmental information from multiple sources.
  - Processes data and determines whether an eco-lane should be created or decommissioned along a roadway.
  - Readily adapts to actual and predicted traffic volumes and environmental conditions so that the traffic network operation is optimized to reduce emissions.
  - Establishes parameters for eco-lanes including the locations of the eco-lanes. Parameters may include:
    - Number of lanes of the roadway that will be dedicated as eco-lanes
    - Start and end time for the eco-lanes
    - Criteria for vehicles entering the eco-lanes
    - Parameters for vehicle platooning
- Manages operational strategies (e.g., eco-speed limits, ramp metering, and vehicle platooning) in the eco-lanes with the objective of reducing fuel consumption and overall emissions along the roadway segment.
- Provides traveler information and shares information about the eco-lane with regional jurisdictions to support coordinated operations.


ACTORS THAT PROVIDE INPUTS
Traffic Management Centers
Connected Vehicle Roadway Equipment
ITS Roadway Equipment
Emissions Management Centers
Operator
ECO-LANES SYSTEM
Data Collection Element
Traffic Data Collection
Environmental Data Collection
Field Device Status Data Collection
Vehicle Specific Data Collection
Operator Input
Data Processing Element
Real-Time and Predicted Traffic Conditions
Real-Time and Predicted Environmental Conditions
Eco-Ramp Meter Timing
Eco-Speed Limits
Vehicle Platooning Parameters
Eco-Lanes Parameters
Eco-Lane Violations
Data Dissemination Element
Traffic and Environmental Conditions Dissemination
Eco-Ramp Meter Timing Dissemination
Eco-Speed Limit Dissemination
Vehicle Platooning Parameters Dissemination
Eco-Lane Parameters Dissemination
Eco-Lane Violation Dissemination
Data Storage & Archive Element
Data Archive
User Interface
User Interface
ACTORS THAT RECEIVE OUTPUTS
Traffic Management Centers
Connected Vehicle Roadway Equipment
ITS Roadway Equipment
Emissions Management Centers
Enforcement Agencies
Operator

Back Office

ECO-LANES SYSTEM

Data Collection Element

1. ELS-DC-01: Collect Traffic Data
2. ELS-DC-02: Collect Environmental Data
3. ELS-DC-03: Collect Field Device Status Data
4. ELS-DC-04: Collect Vehicle Specific Data
5. ELS-DC-05: Collect Operator Input

Data Processing Element

1. ELS-DP-01: Process Traffic Data
2. ELS-DP-02: Generate Predicted Traffic Conditions and Forecast Demand
3. ELS-DP-03: Process Environmental Data
4. ELS-DP-04: Generate Predicted Emissions Profile
5. ELS-DP-05: Generate Ramp Meter Timing Strategy
6. ELS-DP-06: Generate Eco-Speed Limits
7. ELS-DP-07: Generate Vehicle Platooning Parameters
8. ELS-DP-08: Create and Decommission Eco-Lanes
9. ELS-DP-09: Detect Violations for Individual Vehicles

Data Storage and Archive Element

1. ELS-DA-01: Archive Data
2. ELS-DA-02: Determine Performance Measures

Data Dissemination Element

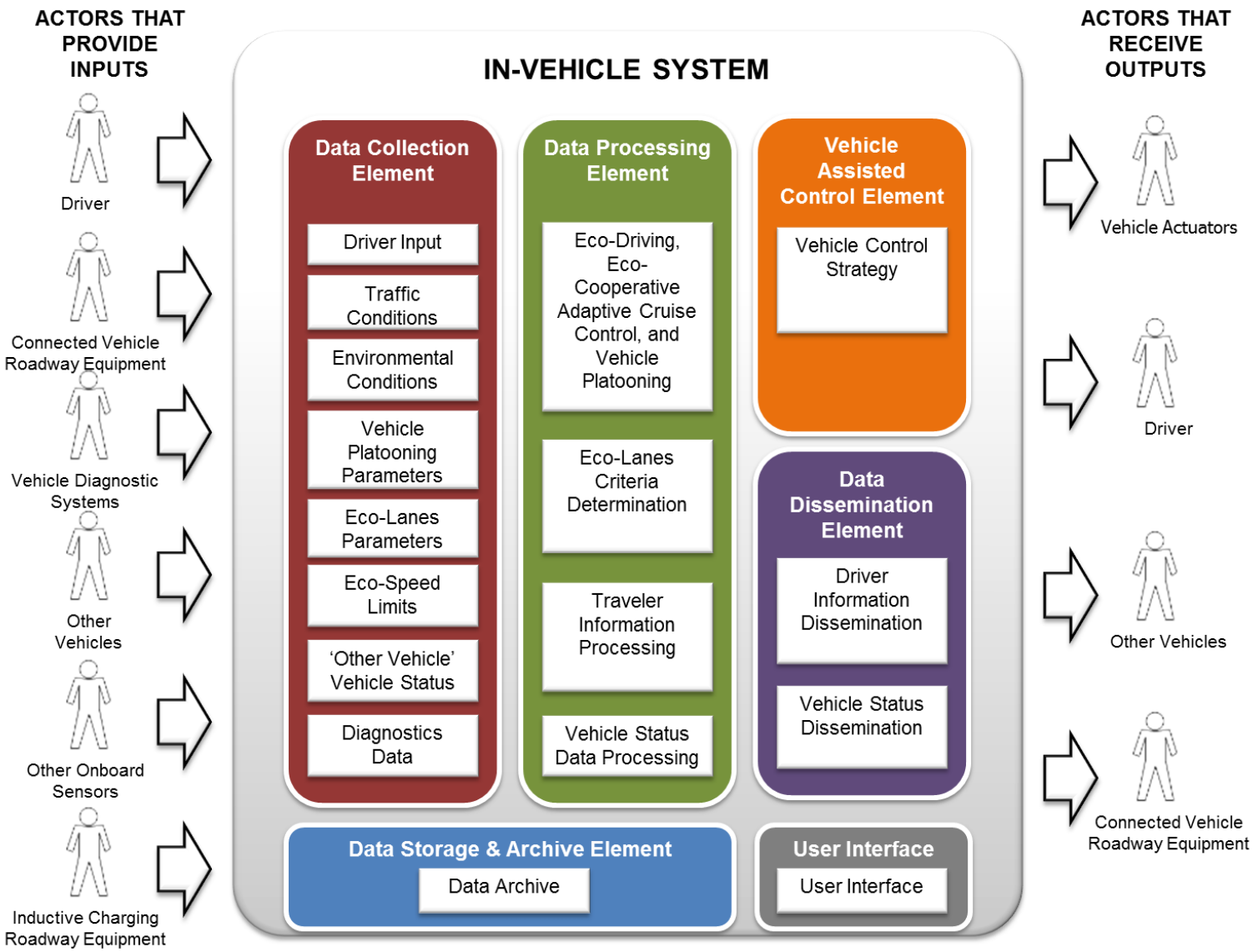
1. ELS-D-01: Provide Ramp Meter Timing Plans to Roadway Equipment
2. ELS-D-02: Disseminate Traffic Conditions to Other Centers
3. ELS-D-03: Disseminate Traffic Conditions for the Eco-Lanes and Regular Lanes to Vehicles
4. ELS-D-04: Disseminate Environmental Conditions to Other Centers
5. ELS-D-05: Disseminate Environmental Conditions to Vehicles
6. ELS-D-06: Disseminate Eco-Speed Limits to Vehicles
7. ELS-D-07: Disseminate Vehicle Platooning Parameters
8. ELS-D-08: Disseminate Eco-Lanes Parameters
9. ELS-D-09: Disseminate Eco-Lanes Parameters to Other Centers
10. ELS-D-09: Provide Notice of Violation to Vehicles
11. ELS-D-10: Notify Enforcement Agencies of Violations

User Interface Element

1. ELS-UI-01: User Interface

In-Vehicle System

- The In-Vehicle System:
  - Collects information about the eco-lanes, as well as traffic and environmental conditions, and presents this information to the driver to assist him or her in making informed pre-trip and en-route travel choices.
  - Provides real-time advice to drivers so that they can adjust driving behavior to save fuel and reduce emissions. The advice includes recommended driving speeds, optimal acceleration, and optimal deceleration profiles on freeways.
  - Supports eco-driving, eco-cooperative adaptive cruise control (eco-CACC), and vehicle platooning applications.
  - Collects emissions data from vehicle diagnostic systems or other on-board sensors to disseminate these data to Connected Vehicle Roadway Equipment. These data would be used by the Eco-Lanes System – located at a center – to determine:
    - Eco-lane parameters
    - Vehicle platooning parameters
    - Eco-speed limits, ramp metering plans, and other traffic control strategies.


ACTORS THAT PROVIDE INPUTS
Driver
Connected Vehicle Roadway Equipment
Vehicle Diagnostic Systems
Other Vehicles
Other Onboard Sensors
Inductive Charging Roadway Equipment
IN-VEHICLE SYSTEM
Data Collection Element
Driver Input
Traffic Conditions
Environmental Conditions
Vehicle Platooning Parameters
Eco-Lanes Parameters
Eco-Speed Limits
'Other Vehicle' Vehicle Status
Diagnostics Data
Data Processing Element
Eco-Driving, Eco-Cooperative Adaptive Cruise Control, and Vehicle Platooning
Eco-Lanes Criteria Determination
Traveler Information Processing
Vehicle Status Data Processing
Vehicle Assisted Control Element
Vehicle Control Strategy
Data Dissemination Element
Driver Information Dissemination
Vehicle Status Dissemination
Data Storage & Archive Element
Data Archive
User Interface
User Interface
ACTORS THAT RECEIVE OUTPUTS
Vehicle Actuators
Driver
Other Vehicles
Connected Vehicle Roadway Equipment

Vehicle

IN-VEHICLE SYSTEM

Data Collection Element

1. IVS-DC-01: Collect Driver Input
2. IVS-DC-02: Receive Traffic Conditions Data
3. IVS-DC-03: Collect Geographic Information Description Data
4. IVS-DC-04: Receive Environmental Conditions Data
5. IVS-DC-05: Receive Vehicle Platooning Parameters
6. IVS-DC-06: Receive Eco-Lanes Parameter Information
7. IVS-DC-07: Receive Eco-Speed Limits
8. IVS-DC-08: Receive Vehicle Status Data from Other Vehicles (i.e., BSM)
9. IVS-DC-09: Collect Vehicle Diagnostics Data
10. IVS-DC-10: Receive Inductive Charge

Data Processing Element

1. IVS-DP-01: Generate Eco-Driving Strategies
2. IVS-DP-02: Determine if Vehicle Meets Criteria for Vehicle Platooning
3. IVS-DP-03: Generate Eco- Cooperative Adaptive Cruise Control and Vehicle Platooning Strategies
4. IVS-DP-04: Determine if the Vehicle Meets Criteria to Enter the Eco-Lanes
5. IVS-DP-05: Process Traffic and Environmental Data for Traveler Information Messages
6. IVS-DP-06: Determine Vehicle Emissions Data

Data Dissemination Element

1. IVS-D-01: Disseminate Vehicle Status Data
2. IVS-D-02: Disseminate Vehicle Status Environmental Data
3. IVS-D-03: Provide Traffic Conditions to the Driver
4. IVS-D-04: Provide Environmental Conditions to the Driver
5. IVS-D-05: Provide Eco-Lanes Parameters to the Driver
6. IVS-D-06: Provide Vehicle Platooning Parameters to the Driver
7. IVS-D-07: Provide Eco-Driving Information to the Driver

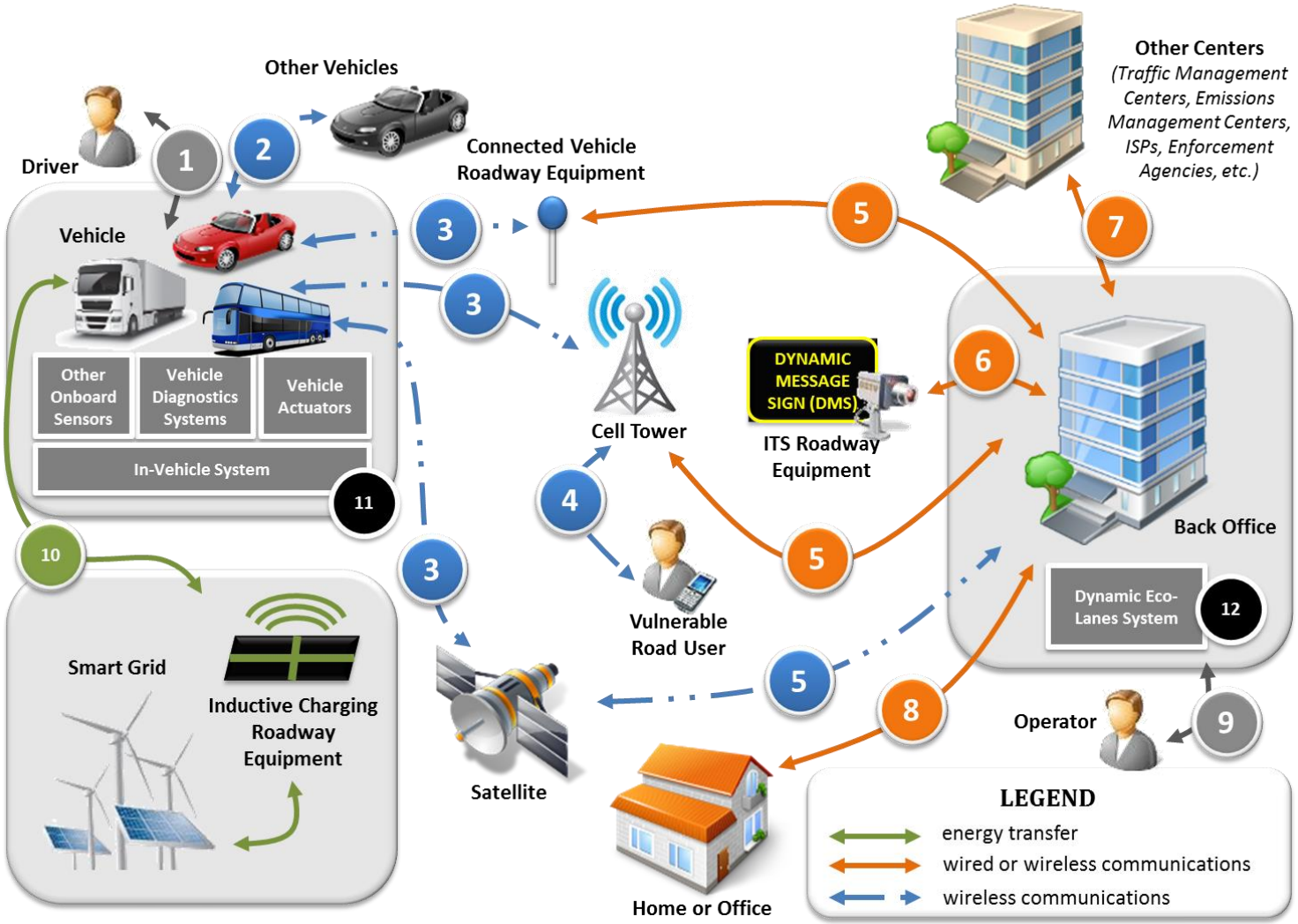
Vehicle Control Element

1. IVS-VC-01: Provide Eco-Driving Vehicle Assisted Control Strategy

Driver Interface Element

1. IVS-DI-01: Provide Driver Interface

Eco-Lanes

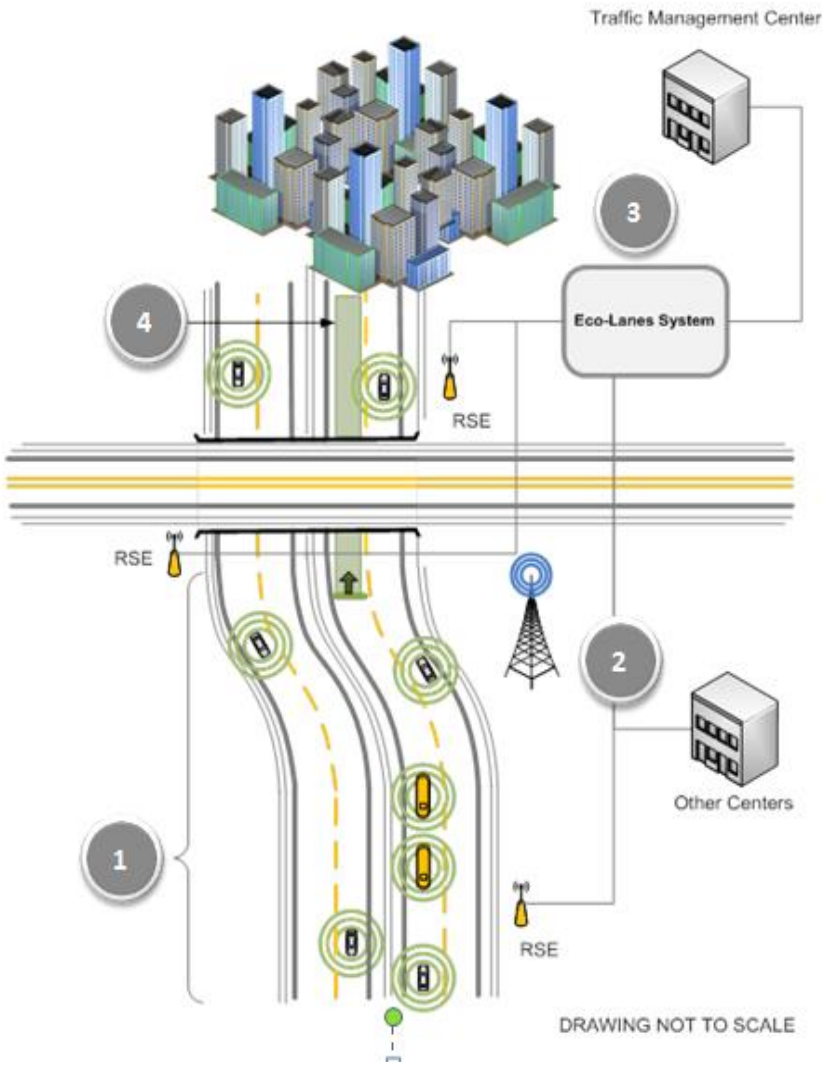

Other Vehicles
Driver
1
2
Connected Vehicle Roadway Equipment
Other Centers (Traffic Management Centers, Emissions Management Centers, ISPs, Enforcement Agencies, etc.)
Vehicle
3
3
5
7
Other Onboard Sensors
Vehicle Diagnostics Systems
Vehicle Actuators
In-Vehicle System
11
Cell Tower
DYNAMIC MESSAGE SIGN (DMS)
ITS Roadway Equipment
6
Back Office
4
5
10
3
Vulnerable Road User
Dynamic Eco-Lanes System
12
Smart Grid
Inductive Charging Roadway Equipment
5
8
Operator
9
Satellite
Home or Office
LEGEND
energy transfer
wired or wireless communications
wireless communications

Eco-Lanes

Table 8-1: Eco-Lanes Interfaces and Data Exchanges

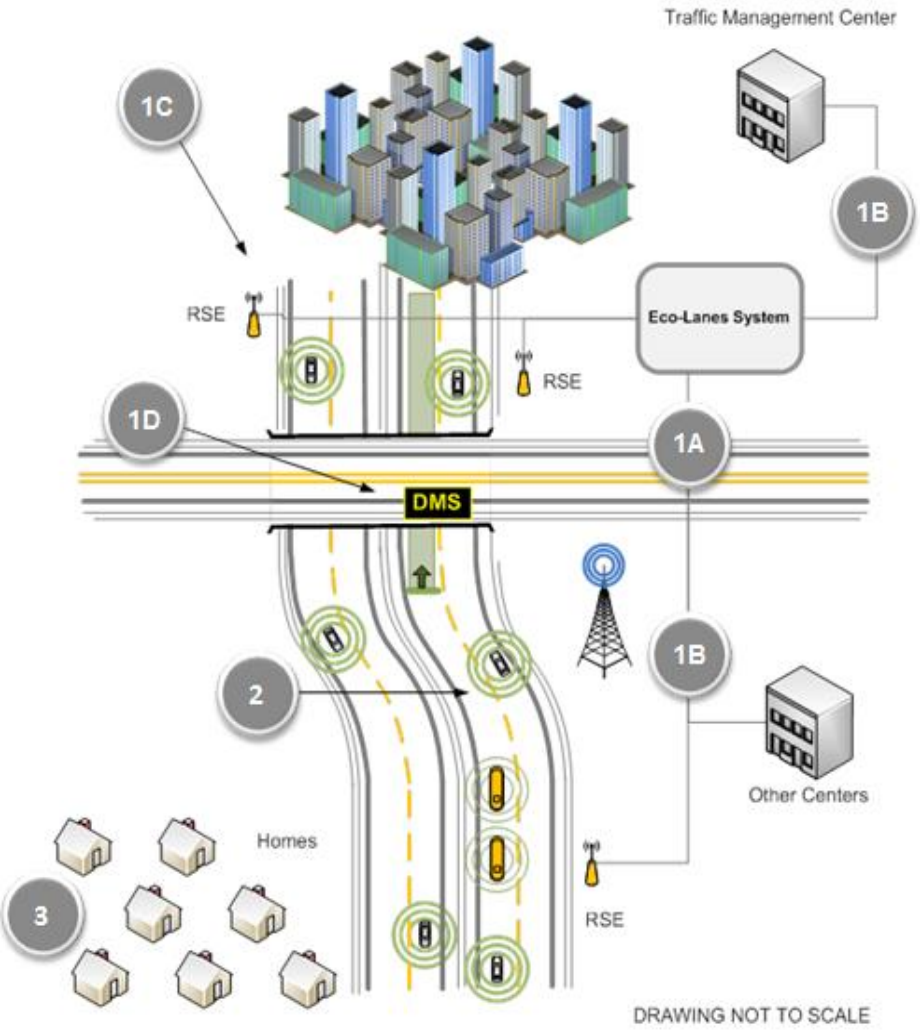
Item	Actors	Data Exchange / Action	Related User Needs
1	In-Vehicle System and Driver	<u>In-Vehicle System sends to Driver</u> • Eco-Lanes Parameter Information (e.g., location, entrance criteria, eco-speed limits, etc.) • Vehicle Platooning Parameters (e.g., locations, number of vehicles, speeds, etc.) • Eco-driving Information • Traffic conditions • Environmental conditions (e.g., code red air quality alerts) • Road weather conditions • Status of an electric vehicle's electric charge and charge received from inductive charging field infrastructure <u>Driver Sends to In-Vehicle System</u> • Activation of Application (e.g., activate eco-cooperative adaptive cruise control) • Updates to configurable parameters	• IVS-DC-01: Collect Driver Input • IVS-D-03: Provide Traffic Conditions to the Driver • IVS-D-04: Provide Environmental Conditions to the Driver • IVS-D-05: Provide Eco-Lanes Parameters to the Driver • IVS-D-06: Provide Vehicle Platooning Parameters to the Driver • IVS-D-07: Provide Eco-Driving Information to the Driver • IVS-DI-01: Provide Driver Interface
2	In-Vehicle System and Other Vehicles	<u>In-Vehicle System sends to Other Vehicles</u> • Vehicle status data (e.g., BSM data including vehicle's location, heading, speed, acceleration, braking status, size, etc.) <u>Other Vehicles send to In-Vehicle System</u> • Vehicle status data (e.g., BSM data including vehicle's location, heading, speed, acceleration, braking status, size, etc.)	• IVS-DC-08: Receive Vehicle Status Data from Other Vehicles • IVS-D-01: Disseminate Vehicle Status Information

Eco-Lanes: Establishing an Eco-Lane



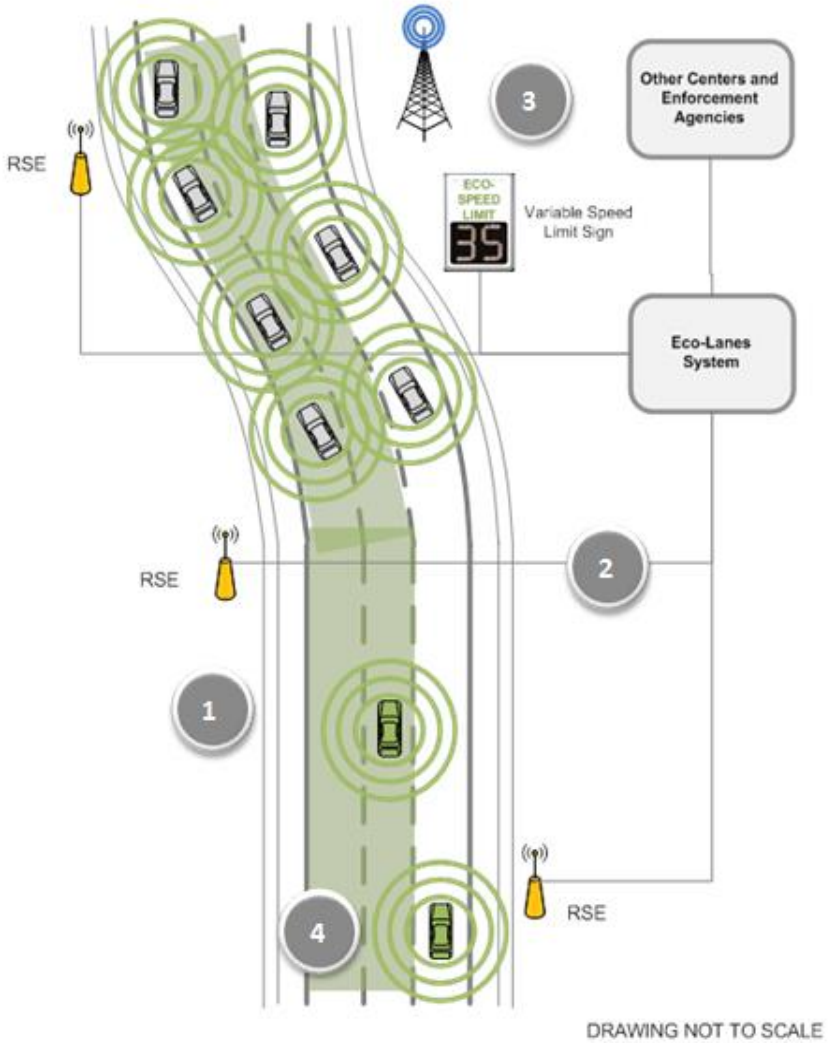
Step	Description
1	**In-Vehicle Systems collect data from vehicle diagnostic systems and other onboard systems about the vehicle's emissions and vehicle's status (e.g., current speed, acceleration, location, etc.). These data are sent to Connected Vehicle Roadway Equipment using DSRC, cellular, or other wireless communications**.
2	**Other Centers provide traffic, environmental, and transit data to the Eco-Lanes System. Traffic data includes volumes, speeds, occupancy, travel times, incidents, or other traffic data collected by a Traffic Management Center.** These data may be collected using ITS Roadway Equipment such as traffic sensors, probe vehicles, or other ITS technologies. **Environmental data includes air quality data or weather data collected by Emissions Management Centers.**
3	**The Eco-Lanes System uses the data collected from Connected Vehicle Roadway Equipment, ITS Roadway Equipment, and Other Centers** to determine whether an eco-lane should be established, and if so, the parameters of the eco-lane. **These parameters include the geographic limits of the eco-lane, the duration of the eco-lane, and types of vehicle permitted to use the eco-lanes (i.e., the eco-lanes may restrict high emitting vehicles from using the lanes).**
4	The eco-lane is established by the Eco-Lanes System and is approved by the operator. **The Eco-Lanes System geo-fences the geographic limits of the eco-lane and assigns parameters including the types of vehicles permitted to use the eco-lanes.**

Eco-Lanes:
Eco-Lanes Traveler Information



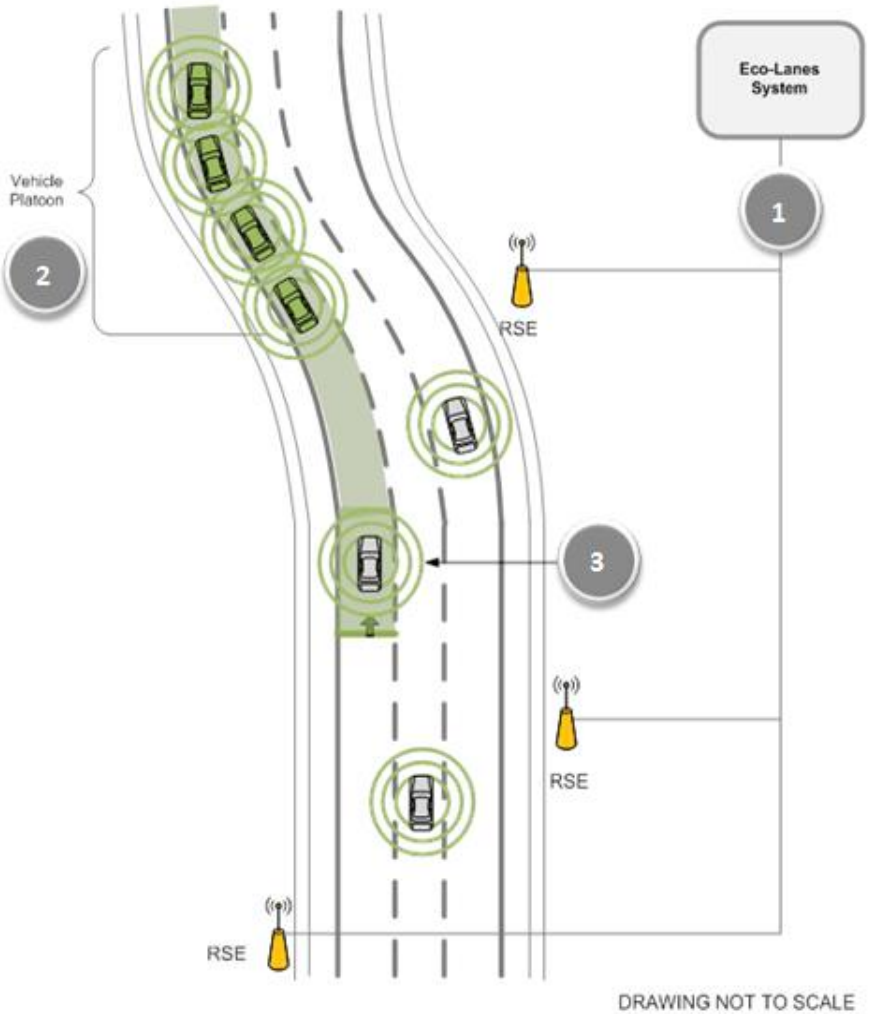
Step	Description
1	**Step 1 A:** The Eco-Lanes System determines the parameters for the eco-lanes. **Step 1 B: The Eco-Lanes System sends parameters about the eco-lanes to Other Centers such as Traffic Management Centers and Transit Management Centers.** These centers use information about the eco-lanes to support their traffic and transit operations in the vicinity of the eco-lanes. **Step 1 C: Connected Vehicle Roadside Equipment broadcast messages about the parameters of the eco-lanes.** Messages may be broadcast using DSRC communications or other wireless communications (e.g., 4G). **Step 1 D: ITS Roadway Equipment including Message Signs and 511 Systems provide information about the parameters of the eco-lanes.**
2	**In-Vehicle Systems receive information about the parameters of the eco-lanes.** This information is presented to drivers to assist them in making informed en-route travel choices as they approach the eco-lane. **Prior to entering the eco-lane, drivers would be presented with comparisons of travel times and estimated fuel consumption for using the eco-lanes versus the regular lanes.** The traveler information would also inform the driver if his or her vehicle is permitted to use the eco-lane.
3	**Travelers receive pre-trip traveler information about the parameters of the eco-lanes and other traveler information. This information may be received by travelers from Information Service Providers on their personal computers, cell phones, tablets, television, radio, or 511 traveler information systems. Travelers use this information to plan their trips accordingly.** For example, upon receiving information about the eco-lanes, travelers may to use their alternative fuel vehicle to drive into Metropolis City.

Eco-Lanes: Eco-Speed Harmonization



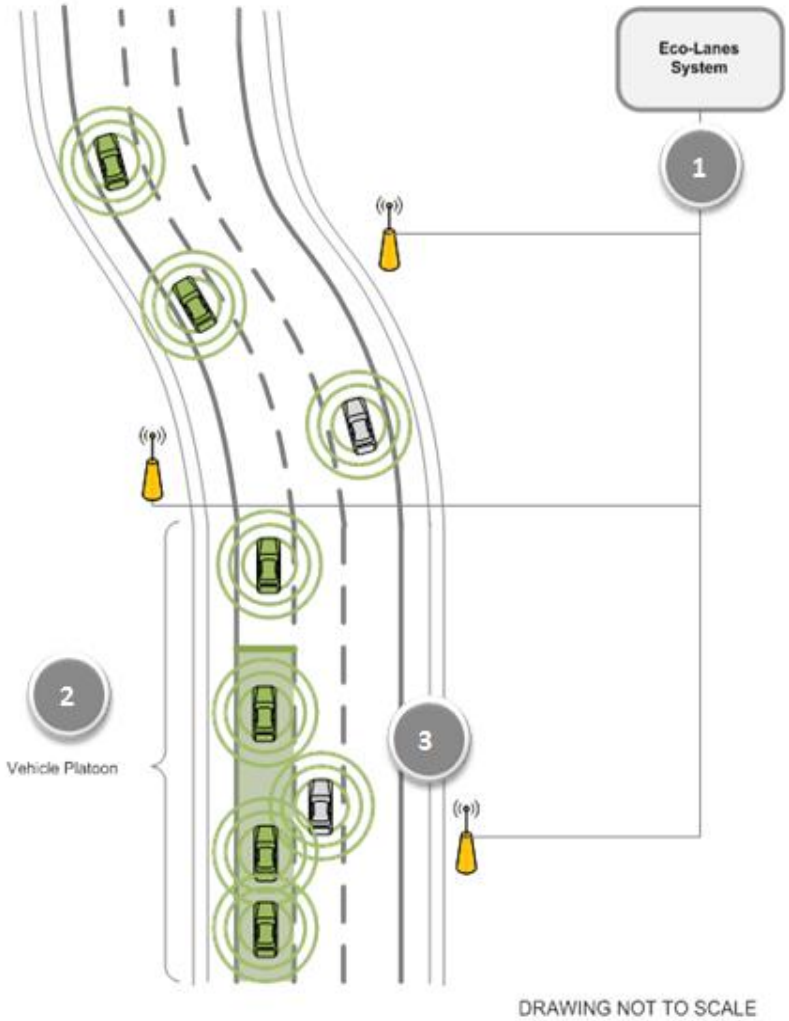
Step	Description
1	**In-Vehicle Systems collect data from vehicle diagnostic systems and other onboard systems about the vehicle's emissions and vehicle's status (e.g., current speed, acceleration, location, etc.). These data are sent to Connected Vehicle Roadway Equipment using DSRC, cellular, or other wireless communications.**
2	**The Eco-Lanes System collects vehicle status data from vehicles traveling in an eco-lane. This information along with historical traffic conditions, and data collected from roadway sensors are used to calculate environmentally optimized speed limits for the eco-lane(s).** The speed limits also consider congestion and incidents to slow the speed of vehicles approaching the back of a queue. **Eco-speed limits are determined for each roadway segment and are specific to a travel lane. Lane specific eco-speed limits need to be determined to differentiate speeds for eco-lanes versus regular lanes running adjacent to the eco-lanes.** The system **updates the eco-speed limit every 5 minutes** based on real-time and predicted traffic conditions.
3	**The Eco-Lanes System sends eco-speed limit information to VSL signs and to Connected Vehicle Roadway Equipment.**
4	**In-Vehicle Systems receive eco-speed limits disseminated by Connected Vehicle Roadway Equipment and present this information to the driver.** The eco-speed limits are lane specific, so the speed limits allow the eco-lanes to be different than the speed limits for the regular lanes. **Upon receiving the eco-speed limits, drivers adjust their vehicle's speed accordingly. In the future, if automated systems are incorporated into vehicles, the vehicle may automatically adjust its speed according to the eco-speed limit.**

Eco-Lanes: Eco-CACC (Vehicle Entering a Platoon)



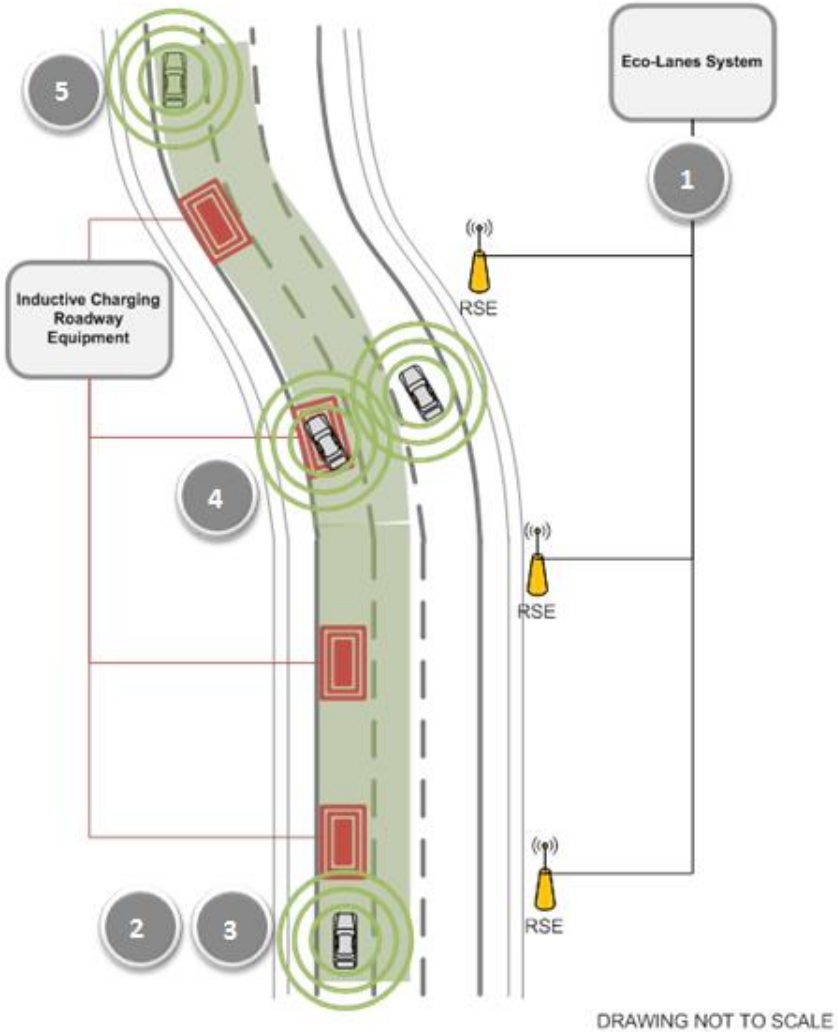
Step	Description
1	**The Eco-Lanes System disseminates vehicle platooning parameters including the geographic limits (start and end locations) for vehicle platooning capabilities, as well as, speed, and gap strategies for the platoon.**
2	**Vehicles in a vehicle platoon disseminate parameters about the platoon including the speed of the platoon, number of vehicles in the platoon, location of the platoon, and type of vehicles in the platoon (e.g., platoons may be limited to trucks or transit vehicles).** This information is broadcast using V2V DSRC. *Note: The lead vehicle in the platoon is an autonomous vehicle.*
3	**A vehicle approaching the back of the platoon meets the security requirements to enter the platoon and has been approved by the operating entity to join the platoon. The vehicle's In-Vehicle System receives information about the nearby platoon and its parameters.** As the vehicle approaches the end of the vehicle platoon, **the driver confirms through the In-Vehicle System that he wants to join the platoon. The vehicle's In-Vehicle System sends a message to the last vehicle in the platoon requesting the vehicle to join the platoon. The last vehicle in the platoon accepts the request. The vehicle "attaches" itself to the platoon**. The driver is notified that he has joined the platoon and has been **released from lateral and longitudinal movement of the vehicle while his vehicle is in the platoon.** Vehicles travel with small gaps, reducing aerodynamic drag. V2V communication allows vehicles to accelerate or brake with minimal lag to maintain the platoon with the lead vehicle. The reduction in drag results in reduced fuel consumption, greater fuel efficiency, and less pollution for vehicles.

Eco-Lanes: Eco-CACC (Vehicle Leaving a Platoon)



Step	Description
1	**The Eco-Lanes System disseminates a message containing location for the end of the vehicle platooning lane. The message also includes information to assist the vehicles in the vehicle platoon in merging with the regular lanes including recommended gaps and speeds for the vehicles as they leave the platoon.** These recommended speeds and gaps are based on real-time traffic conditions in the eco-lanes and regular lanes. **The message is broadcasted by Connected Vehicle Roadway Equipment using DSRC or other wireless communications (e.g., 4G).**
2	**Vehicles in the platoon receive the message about the end of the platooning lane and information about recommended speeds and gaps** as the vehicles merge with the regular lanes. **Prior to the end of the vehicle platooning lanes, the gaps between vehicles increases and the vehicle speeds decrease. The larger gaps between vehicles continue to increase until a threshold is met and the driver is alerted that control of the vehicle will be given back to the driver.**
3	**Vehicles in the regular lanes receive messages that the vehicle platooning lanes are ending. The vehicles also receive messages with recommended speeds specific to the regular lanes to assist with upcoming merge and possibly messages directing them to move to the right lane.** This information is provided to drivers who manually adjust their vehicle's speed.

Eco-Lanes: Dynamic Inductive Charging



Step	Description
1	The Connected Vehicle Roadway Equipment broadcasts parameters about the eco-lanes. **These parameters include information about the location of inductive charging infrastructure in the eco-lanes.**
2	**The In-Vehicle System receives messages about the parameters for the eco-lanes – including the location of inductive charging infrastructure. The driver of the electric vehicle opts into an inductive charging application.** The application informs the driver of the location of inductive charging infrastructure.
3	**As the vehicle approaches the first inductive charging pad, the vehicle establishes a wireless connection with the inductive charging infrastructure. A handshake process begins, payment information is sent to inductive charging equipment, and an electric charge is transferred from the pad to the vehicle.**
4	**As the vehicle drives in the eco-lanes, it passes over wireless inductive charging pads.** Each time the vehicle is positioned over the pad and the vehicle's application is activated, the vehicle receives energy from the pads. **A series of inductive charging pads embedded in the roadway enable 'dynamic charging' which allows charging of vehicles in motion.**
5	**The vehicle stops receiving energy from the inductive charging pads when one of the following criteria is met: (1) the vehicle's battery is fully charged, (2) the driver opts out of the inductive charging application, or (3) the vehicle passes over the last charging pad. Upon termination, transfer of payment is made for the energy transferred.**

Policy Considerations

- Would certain vehicle types be allowed to use eco-lanes at a higher priority than other vehicle types?
- Are there mobility tradeoffs? If so, how do operating entities make a decision to optimize for the environment instead of optimizing for mobility?
- How can this Operational Scenario facilitate “green” choices by:
  - Drivers,
  - State and local DOT’s operating the transportation system, and
  - Decision Makers?
- How can this Operational Scenario incentivize “green” choices by:
  - Drivers,
  - State and local DOT’s operating the transportation system, and
  - Decision Makers?
- How does open data sharing and standardization be used to support public and private sector deployment?
- Under what situation(s) would an operating entity choose to implement eco-lanes?
- How do Decision Makers value eco-lanes as an option for investing scarce resources?

Educational Considerations

- What are the social benefits of “green” transportation decisions?
  - Drivers
  - State and local DOT’s operating the transportation system
- What types of educational campaigns could be used to educate the traveling public to make green transportation choices?
- What types of educational campaigns could be used to educate entities operating the transportation network to optimize for the environment?
- How do you incentivize a choice versus another choice? And how do you get people to act on that choice?

Provide travelers and entities operating the transportation network the information they need to make “green” transportation choices

Sources

1. Wang, Z., & Walton, C. M. (2006). *An Investigation on the Environmental Benefits of a Variable Speed Control Strategy*. Springfield: National Technical Information Service.
2. SAfe Road TRains for the Environment **(**SARTRE) Final Report http://www.sartre-project.eu/en/publications/Documents/SARTRE_Final-Report.pdf