Field Testing of Eco-Speed Control Using V2I Communication

Raj Kishore Kamalanathsharma and Dr. Hesham Rakha

Introduction

Eco-speed control refers to controlling or providing speed advisory recommendations to drivers in response to incoming Signal Phasing and Timing (SPaT) information to reduce vehicle fuel consumption levels without compromising safety. The tests are intended to handle four levels of technological barriers in this study (defined by the four study cases defined later). The Smart Road tests will be supplemented with analysis of driver behavior in the Blacksburg test-bed using video data from "live" intersections to draw conclusions on typical driver behavior so that a comparison can be made with respect to the benefits gained. Measures of effectiveness studied will primarily be fuel-consumption, travel-time, delays and if possible emissions.

Research Objectives

The primary objective of the research proposed in this document is to test the eco-speed control system in a real environment and to get a hands-on on the implementation issues of this system. The Smart Road test bed with Connected Vehicles technology is a suitable place to do the first phase of this testing. In addition to studying the implementation issues, the research is anticipated to give valuable inference on at least the following issues:

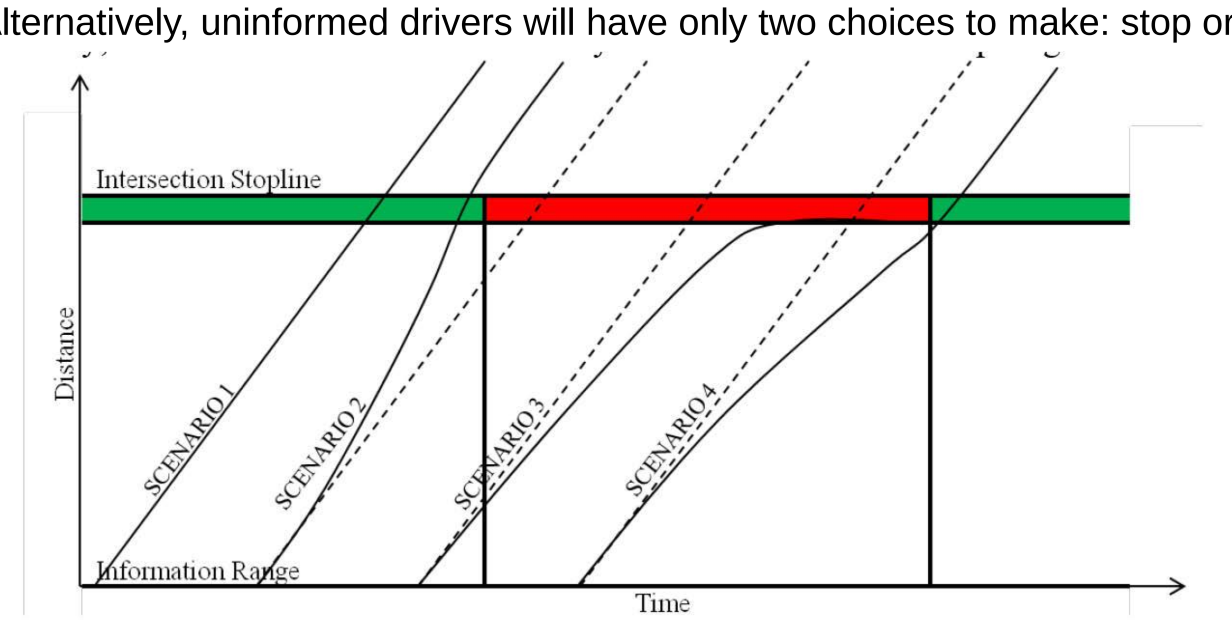
1. Actual benefits sought when eco-speed control or ECACC is implemented and the feasibility of the system.
2. Error functions when a typical driver follows a proposed speed profile.
3. Deviation from the proposed speed profile when an automated cruising unit is used.
4. Driver-Vehicle Interface needed for an eco-speed control unit.
5. Effect of non-test vehicles in the traffic mix on (a) fuel benefits of the test-vehicle and (b) feasibility of speed adjustments.

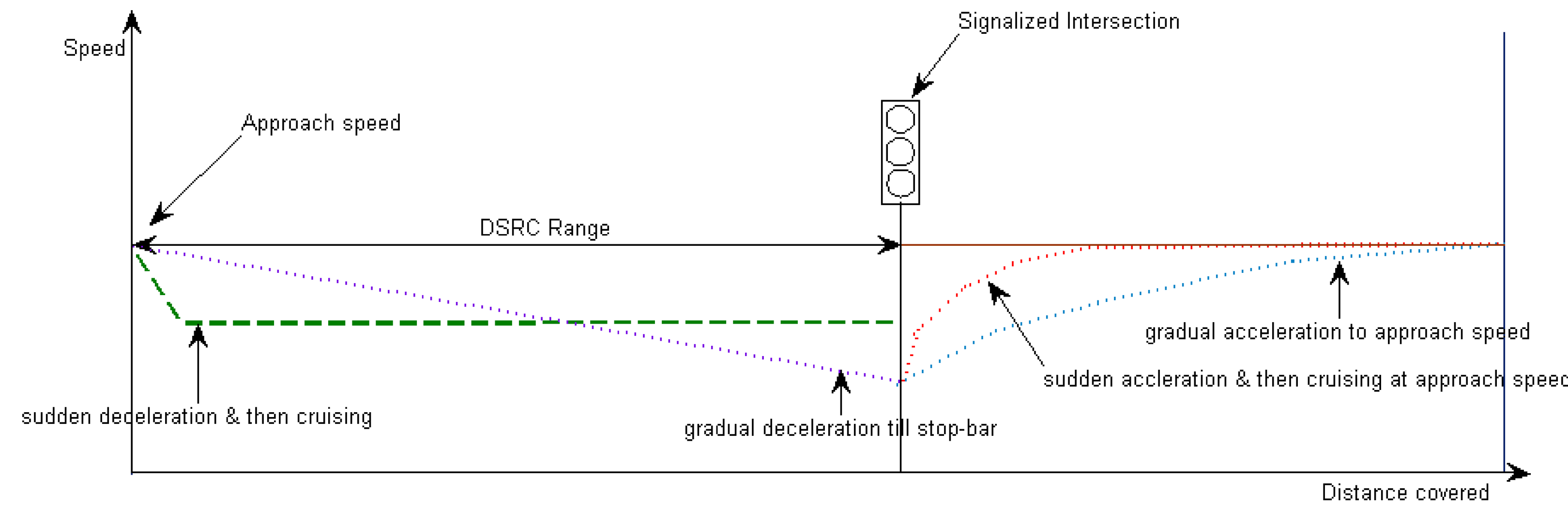
Concept of Operations (CONOPS)

The eco-speed control algorithm uses SPaT information communicated to vehicles to compute fuel-optimum vehicle trajectories through and past signalized intersections. When upcoming signal changes are received by vehicles approaching a traffic signal, the vehicles can alter their speed in anticipation of these changes so as to minimize their fuel consumption. Now if the vehicle is receives SPaT information, it can be categorized to fall in any of the four scenarios mentioned below:

1. Vehicle can continue moving at the same speed with no further actions required.
2. Vehicle needs to safely speed up to the speed limit to make it through the intersection during the current phase.
3. Vehicle is too late to make it to first green phase and too early for the next. So it has to wait and idle for red.
4. Vehicle can slow down slightly to make it to the next green phase.

This categorization can be made possible if SPaT data are shared with approaching vehicles. Alternatively, uninformed drivers will have only two choices to make: stop or go.

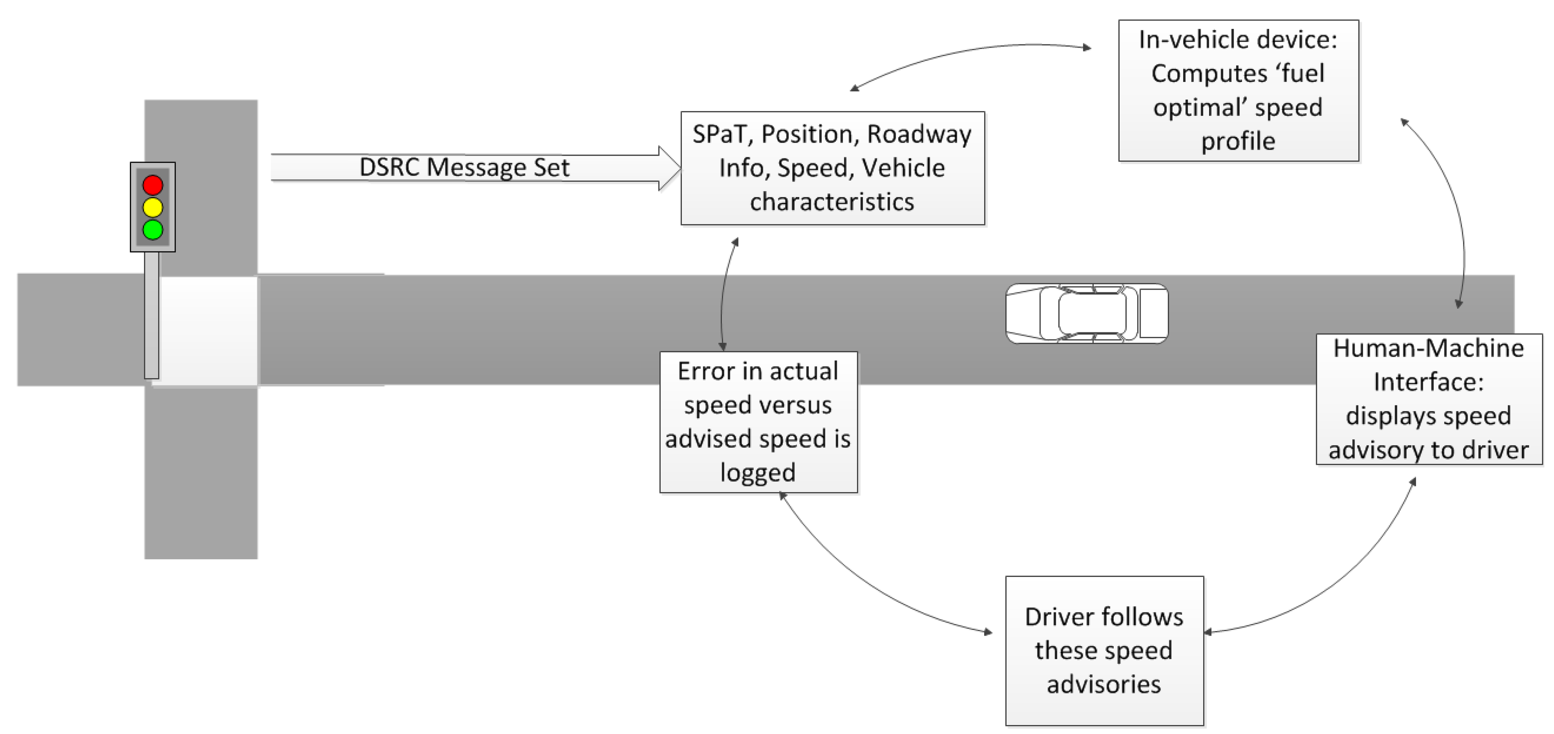




Alternative Vehicle Profiles at a Signal Turning Green from Red

Smart Road Experimentation

Smart Road experiments will be designed to fully utilize the UTC's Connected Vehicles Infrastructure capability and will involve actual implementation of the Eco-Speed Control algorithm in test vehicles using DSRC communication. The Smart-Road intersection's custom controller will be used to create repeatable scenarios to change signal phases based to the vehicle's distance to the intersection (DTI). The Road-Side Equipment (RSE) with wireless capability will be used to communicate this information to the vehicles which will have portable devices generating and updating "fuel-optimum" vehicle trajectories. Driving experiments will involve drivers from different demographics to replicate an actual test population. The vehicle will log the test vehicles' instantaneous speed, throttle levels, brake levels, fuel consumption and the road-grade so that comparison can be made between the cases.



Experimental Set-Up for the Smart Road Intersection

Video/Radar Analysis of Driver Behavior

A typical driver who drives a vehicle that is not instrumented to receive SPaT information will be unaware of upcoming signal changes on his/her route. The driver's perception about the current signal phase will be the decision factor to whether to continue driving or to decelerate their vehicle. The first experiment involves studying the behavior of drivers at intersections without receiving SPaT data. This effort entails the following:

1. Characterizing driver behavior approaching a red signal indication in terms of how they adjust their speed and how they accelerate after the traffic signal indication changes to green.
2. Characterizing typical vehicle accelerations in a queue in order to compute the time it takes to clear a queue of vehicles. This is important in the computation of the required delay depending on the length of the queue.

Four Test Scenarios

Case 1: Uninformed Driver
This will form the base case of experimentation and will involve drivers approaching the intersection in an uninformed manner. There will be no communication of SPaT information or driver advisory in this case. This is expected to replicate the pre-system scenario. This case will also be compared to the behavior extracted from the instrumented signals in the Blacksburg test-bed.

Case 2: Informed Driver
This will involve communication of SPaT information to drivers. The Driver-Vehicle Interface (DVI) will show "seconds to next signal change" to the driver. The driver uses this information and his/her perception about the situation to make speed changes and safely maneuver the intersection.

Case 3: Informed Driver with Speed Advisory
In this case, the SPaT information will be used by the in-vehicle devices to generate the fuel-optimum vehicle trajectory and then communicate the instantaneous speed recommendation to the driver using the DVI. The suggested speed and actual speed will be logged and could be used to generate an error function. The speed advisory will be updated every time-step to incorporate driver's error in following the previous advisory.

Case 4: ECACC System*
ECACC system test could be done if a specified speed profile could be implemented in a test-vehicle's cruise control system by enhancing the Adaptive Cruise Control system. This case is similar to the previous one except that the driver perception on speed-following will not come in to play. The cruise control's latency to follow speed will be studied in this case and will give a more accurate replica of the proposed algorithm.

Once the four cases are experimented, the logged data will be used to generate meaningful inferences on many research questions including the following:

a. What are the implementation issues with respect to eco-speed control systems?
b. What percentage fuel-savings can be expected from providing speed-advisories to drivers?
c. What percentage of fuel-savings can be expected just by giving "seconds-to-next-signal-change" information to the drivers? Such systems already exist in many European and Asian countries on an infrastructure-based display system.
d. What is the error-function with which a typical driver can follow instantaneous speed-advisories?

Anticipated Results and Benefits

The proposed study will be the first of its kind field-testing of the proposed Eco-Speed Control Algorithm and will enable comparing simulation results with field study results. The study will also serve as the first step to identify implementation issues associated with Eco-Cooperative Adaptive Cruise Control and Eco-Speed Control strategies. This research will also address the issues of driver-acceptance of intelligent advisories such as how humans respond to alerts from an in-vehicle device or with what error humans or automated cruising devices can follow a particular advised speed profile. The error function generated for speed-following can be of high research value for studies involving speed-following.