Smart Cruise Control: An ITS Application for Improved Fuel Economy, Safety, and Traffic Congestion

The U.S. Department of Transportation's (DOT's) Connected Vehicle Program promises significant advances in safety, mobility and the environment. Some of the greatest challenges in transportation today are associated with reducing fuel consumption and vehicle emissions, improving safety on the roadway, and increasing the efficiency of use of the highway infrastructure, which is becoming increasingly congested. These problems are at the root of current objectives to reduce our nation's dependency on fossil fuels, reduce greenhouse gas emissions and improve the nation's transportation infrastructure, thereby improving our security and developing a sustainable energy and transportation future. Reducing the amount of braking done by a vehicle, by anticipating what is ahead and adjusting speed more gradually before arriving at the site where braking would be required, results in improvements in both fuel economy and safety. More stable speeds on the roadway with reduced areas of stopped traffic can also improve the throughput of traffic over a given region. To address these issues, it is proposed to develop a new "Smart" Cruise Control system that would incorporate the following:

- GPS positioning and route planning to identify elevation variations and curves in the road ahead
- On-vehicle trajectory modeling and an optimization routine that calculates a planned speed profile that minimizes braking
- Vehicle-to-vehicle (V2V) communications to provide detailed real-time and near-term future traffic conditions along the planned route via sharing of the planned vehicle speed and position profile data
- Active control of the vehicle's speed so that it will not be excessive relative to (i) the speed limit, (ii) a safe speed while the vehicle traverses curves along its route (based on a maximum acceptable lateral acceleration), or (iii) slowed traffic.

The element of estimating the vehicle's future speed and position and comparing this with the positions of other Smart Cruise-enabled vehicles allows decelerations to be planned so they take place primarily through coasting as opposed to braking at the last moment. Traffic signal phase and timing data can also be used to improve the speed predictions and further reduce the need for braking. This reduction in braking and the subsequent accelerations can significantly reduce vehicle fuel consumption, particularly during stop-and-go driving. The trajectory model can be implemented using a physics-based analysis accounting for all energy losses from the vehicle—including friction in the vehicle drivetrain, tire rolling resistance and aerodynamic drag. A simple model can be computationally efficient while allowing an accurate estimate of the vehicle's trajectory for optimal efficiency and sharing of look-ahead data.

Such a system can be developed primarily by integrating existing technologies and the fuel economy and safety benefits during off-highway travel can be significant. This system can be retrofitted to the current vehicle fleet, which would allow the improvements to take effect much more quickly than what could be achieved with systems requiring infrastructure changes or that could not be implemented through an upgrade or retrofit. The Smart Cruise Control system is also applicable to both passenger and commercial vehicles. Furthermore, additional functionality can be added to the system with newer vehicles and improved infrastructure that can compound the improvements in fuel economy and traffic throughput efficiency of the road system.

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Fuel Economy Benefits

Initial results from fuel economy modeling are very promising. The mechanical energy input to the wheels for acceleration can be reduced by up to 70% when the drive cycle is fully optimized with the Smart Cruise Control system, yielding fuel savings over 30%. Additionally, emissions can be significantly reduced.

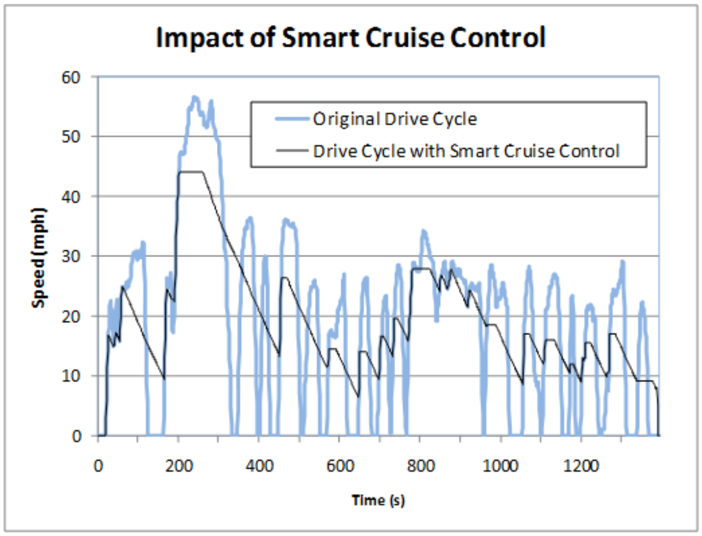

Figure 1. Drive Cycle With and Without Smart Cruise Control.

Table 1. Fuel Economy and Emissions Estimates from Autonomie Vehicle Performance Analysis Software

Model result	Original Drive Cycle	Optimized Drive Cycle
Fuel Economy (mpg)	35.4	53.0
Fuel consumed (gal)	0.21	0.14
NO_x Emissions (g)	4.7	2.3
CO Emissions (g)	9.7	7.8

Future Efforts

As Connected Vehicle technologies become more advanced and are widely adopted, the Smart Cruise Control system can be linked with a ground-based system that performs traffic modeling, optimizes traffic signal timing and re-routes vehicles so that traffic throughput can be maximized. Vehicle-to-Infrastructure (V2I) communications will provide the Smart Cruise Control system with information regarding upcoming traffic signal changes, which further improves the automated look-ahead capabilities. Additional research is needed to quantify the benefits of the system on traffic performance and to complete the development of Smart Cruise Control and integrate it with other ITS systems.

The improvements offered by the Smart Cruise Control system will provide a tangible first step to many of the planned advancements in transportation infrastructure envisioned under the Connected Vehicle and Intelligent Transportation Systems (ITS) initiatives. This technology, however, can be developed within a timeframe of only a few years and can serve as an early demonstration of the advancements planned for these programs.