Impacts of Eco-driving on Passenger Vehicle Use and Greenhouse Gas Emissions

Policy Brief

Kristin Lovejoy and Susan Handy, University of California, Davis
Marlon G. Boarnet, University of Southern California

October 10, 2013

Policy Brief: http://www.arb.ca.gov/cc/sb375/policies/ecodriving/ecodriving_brief.pdf

Technical Background Document:
http://www.arb.ca.gov/cc/sb375/policies/ecodriving/ecodriving_bkgd.pdf

California Environmental Protection Agency
Air Resources Board

Policy Brief on the Impacts of Eco-driving on Passenger Vehicle Use and Greenhouse Gas Emissions

Kristin Lovejoy and Susan Handy, University of California, Davis
Marlon G. Boarnet, University of Southern California

Policy Description

Eco-driving is a style of driving that saves energy, improving fuel economy and reducing tailpipe emissions per mile traveled. Eco-driving tactics include accelerating slowly, cruising at more moderate speeds, avoiding sudden braking, and idling less, as well as selecting routes that allow more of this sort of driving. Three different types of strategies are used to promote eco-driving. Educational campaigns and driver training can encourage adoption of eco-driving tactics. Policies and regulations can help induce eco-driving, for example by setting and enforcing highway speed limits and instituting anti-idling ordinances. Finally, in-vehicle devices that provide real-time feedback on energy use (such as the visual displays in hybrid-electric vehicles), as well as in-vehicle navigational devices providing guidance on route selection and/or traffic conditions, can encourage and track eco-driving for each vehicle. Eco-driving programs may be intended for the general public or targeted to drivers of particular fleets, such as bus drivers, truck drivers, mail-carriers, or other groups of employees.

Research has established that an individual driver's operational tactics can affect fuel economy and emissions. For instance, driving fast is less efficient than cruising at a vehicle's operational optimum, which varies by make and model, but is usually less than 55 mph. Stopping and starting also affect fuel economy, especially in city driving. Experiments with test vehicles on various road types in Belgium found aggressive versus normal driving resulted in 12 to 40% more fuel consumption, with more of a difference for gasoline- than for diesel-powered vehicles (using mid-1990s passenger vehicles of different makes; de Vlieger et al., 2000). Recent experiments in the U.S. showed that ordinary drivers could improve their fuel economy up to 50%, depending on their pre-existing habits and ability to adopt better ones (e.g. Ford, 2008; Reed, 2005).

In general, the potential for eco-driving programs and policies to induce fuel savings depends on current vehicle technology, how much room the existing driving habits of the population at hand leave for improvement, and the effectiveness of programs in inducing drivers to adopt new behaviors.

Impacts of Eco-driving Programs and Policies

Impacts are measured as changes in individual driving behaviors, such as average speed or percentage of time spent in hard acceleration, as well as overall net impact of these behaviors on fuel consumed and emissions levels, following the implementation of an intervention such as an educational campaign, the installation of an in-vehicle feedback device, or implementation of a road management technique, such as speed-limit enforcement.

Effect Size

Of the three types of strategies for promoting eco-driving, empirical evidence is available only for the effect of in-vehicle devices. Three studies have measured the effect of in-vehicle devices displaying real-time energy use on fuel economy for ordinary drivers in naturalistic settings in California (Table 1). Boriboonsomin et al. (2010) found an average reduction of 1% for highway driving and a reduction of 6% for city driving after a device was installed, though this difference was not statistically significant among the 20 drivers included in the study. Martin et al. (2013) found that 10 out of 16 drivers improved fuel economy in the month after the device was installed, with an average of 1.4% improvement (excluding two outliers), though also not statistically significant. Kurani et al. (2013) found a 2.9% average improvement among 118 drivers, which was statistically significant even after controlling for weather, road conditions, and trip types before and after the device was installed.

Table 1. Impact of In-Vehicle Feedback Devices on Average Fuel Consumption

Study	Study location	Sample size	Circumstances controlled for before and after	Change in fuel consumption
Kurani et al., 2013	Davis, CA	118	None	-2.9%*
			Weather, road conditions, trip types	-2.7%*
Martin et al., 2013	San Francisco Bay Area	16	None	-1.4%
Boriboonsomin et al., 2010	Southern California	20	Estimated vehicle specific power	Highway -1% City -6%

* Statistically significant (at p<0.05). Other results shown are not statistically significant.

Evidence Quality

Because these were experimental studies that measured behavior both before and after the installation of an in-vehicle device, they provide a strong means of evaluating of the impact of the intervention. While two of the studies found no statistically significant impact, the small number of participants in those studies (16 and 20, respectively) make significance difficult to establish. It is meaningful that all three studies found that changes to fuel consumption in the same direction (a decrease), with the larger study providing more certain evidence that the intervention does in fact cause a modest improvement in fuel economy among the study participants. However, these studies examined short-term impacts only (one month of driving with the device installed) and are limited to evaluating the impact of the specific type of visual display used in each study, which Kurani et al. (2013) found could differ for different types of drivers. The potential effects of a broader range of programs and contexts are largely unknown.

Caveats

People who more interested in, aware of, and motivated to change their driving behavior may be more likely to participate in these studies compared with the general public, though it is not clear whether that means they would be likely to show more or less of a change in response to the intervention. In general, different behavioral responses may occur in different cultural contexts. For instance, Americans may be less aware than Europeans of fuel economy ranges, as well as more accustomed to marketing focusing on horsepower and acceleration (Barkenbus, 2010). Different vehicle makes and models may require somewhat different eco-driving strategies to maximize efficiency, with today's vehicles different from older technologies. For instance, old carbureted engines ran more smoothly once warmed up, but engines with fuel-injection systems that replaced carburetors in the 1980s and 1990s do not, and so any idling to warm up these cars is a waste. In addition, the type of road, road infrastructure design, terrain, weather, and traffic conditions in which people do most of their driving influence the extent of savings that are possible.

GHG Emissions

Savings in fuel consumption generally correspond to emissions reductions, with CO_2 emissions dropping proportionately with fuel use, and CO and NO_x emissions dropping at a greater rate due to their role as byproducts of hard accelerations (Holmén & Niemeier, 1998; de Vlieger et al., 2000; Van Mierlo et al., 2004). However the magnitude of savings would vary depending on the vehicle technology, type of behavior change, and emission of interest.

Co-benefits

Since eco-driving tactics involve more moderate speeds and less aggressive driving, they also have safety benefits. Widespread adoption would benefit not only those employing them but also other road users. They may reduce driver stress, as well as offer cost-savings to individuals through lower fuel consumption. Eco-driving may also increase "the public's preparedness for possible energy emergencies" (Greene, 1986; pp. 1-2). Finally, heightened awareness about real-time fuel economy could lead to greater awareness of fuel economy ranges for different vehicles, and to more informed purchase decisions.

Examples

Several European countries and Japan have incorporated eco-driving as a part of their national CO_2 reduction programs. The European Union requires eco-driving as part of introductory driver training programs. Many countries have additional promotional campaigns targeting existing drivers, including follow-up training, competitions, and marketing (Barkenbus, 2010; International Transport Forum, 2007). Barkenbus (2010) suggests variety of potential eco-driving policies may be appropriate for U.S. markets, including issuing anti-idling ordinances, reimposing 55mph speed limits, incorporating behavioral strategies as a part of standard driver's education courses, incentivizing matriculation in eco-driving courses (e.g. through insurance-rate discounts), requiring or subsidizing in-vehicle feedback devices or other energy-use feedback mechanisms, and conducting public education or social marketing campaigns. The development of mobile apps, some of which are car-linked and focused on eco-driving, as well as those offering integrated feedback on household/car energy use, is a likely direction for innovation in this area.

The U.S. government ran a Driver Energy Conservation Awareness Training (DECAT) program in 1979-1980 at a facility in Colorado. It included classroom and behind-the-wheel instruction on energy-saving techniques, focusing on drivers of government and private fleets and those who train them (Greene, 1986). Some states implemented programs similar to DECAT or as a part of new drivers' education curriculum. In the early 1980s the Gasoline Conservation Awareness Program (GasCAP) in California (funded by the Energy Commission and sponsored by Caltrans) provided training on trip planning, maintenance, and driving techniques for large vehicle fleets.

In 2004, then Governor Schwarzenegger launched the "Flex Your Power at the Pump" campaign, partnering with state agencies and corporations to promote eco-driving, fleet maintenance, and trip reductions for overall fuel savings among employees and the general public. Participating agencies signed a voluntary "declaration of action" that they would promote eco-driving and other fuel-saving measures as a part of their fleet operations or by educating employees, for instance using lobby signs, posters, flyers, emails, and websites (see Schwarzenegger, 2004; Flex Your Power, 2004).

Another recent statewide campaign is "Drive Clean Across Texas," launched in 2001 and targeting the general population. It provides unified branding for emissions-reduction messages, including a website with fuel-saving tips, links to local area resources, ways to report a smoking vehicle, and vehicle-replacement resources. The program also includes print ads, brochures, TV and radio commercials, as well as free materials targeting K-12 children, including educational posters, a coloring book, a video, and other resources for teachers. The state conducted a promotional sweepstakes, giving away a chance to win a fuel-efficient hybrid-electric vehicle (donated by Ford) and other prizes in exchange for a pledge to do one's part for cleaner air (see http://www.drivecleanacrosstexas.org/).

References

Barkenbus, J.N. (2010). Eco-driving: An overlooked climate change initiative. *Energy Policy* 38, 762-769.

Boriboonsomin, K, Vu, A., & Barth, M. (2010). Eco-Driving: Pilot Evaluation of Driving Behavior Changes among U.S. Drivers. University of California Transportation Center, UCTC-FR-2010-20.

de Vlieger, I., de Keukeleere, D., & Kretzschmar, J.G. (2000). Environmental effects of driving behaviour and congestion related to passenger cars. *Atmospheric Environment* 34, 4649-4655.

Flex Your Power. (2004). Flex Your Power at the Pump Declaration of Action document. Available online: http://www.aqmd.gov/aqmd/doc/flexdecl.doc.

Ford. (2008). Ford tests show eco-driving can improve fuel economy by an average of 24 percent. Press Release, 27 August. (http://media.ford.com/article_display.cfm?article_id=28948).

Greene, D.L. (1986). *Driver Energy Conservation Awareness Training: Review and Recommendations for a National Program.* Oak Ridge, TN: Oak Ridge National Laboratories.

Holmén, B.A., & Niemeier, D.A. (1998). Characterizing the effects of driver variability on real-world vehicle emissions. *Transportation Research Part D: Transport and Environment* 3(2), 117-128.

International Transport Forum. (2007). Workshop on ecodriving: Findings and messages for policymakers, November 22–23. (http://www.internationaltransportforum.org/Proceedings/ecodriving/EcoConclus.pdf).

Kurani, K. S., Stillwater, T, Jones, M., & Caperello, N. (2013). Ecodrive I-80: A large sample fuel economy feedback field test, Final Report. ITS UC Davis Working Paper.

Martin, E.W., Boriboonsomsin, K., Chan, N.D., Williams, N., Shaheen, S.A., & Barth, M. (2013). Dynamic ecodriving in Northern California: A study of survey and vehicle operations data from an ecodriving feedback device. Paper presented at the 92nd Annual Meeting of the Transportation Research Board, Washington, DC.

Reed, P. (2005). We Test the Tips: What Really Saves Gas? And How Much? Edmunds.com. 12 August 2005. (http://www.edmunds.com/fuel-economy/we-test-the-tips.html).

Schwarzenegger, A. (2004.) May 25 letter to California leaders. (http://www.aqmd.gov/aqmd/PDF/flexgovltr.pdf).

Stillwater, T., & Kurani, K. (2012). Preliminary results from a field experiment of three fuel economy feedback designs. ITS UC Davis Working Paper – UCD-ITS-WP-12-01.

Van Mierlo, J., Maggetto, G., Van de Burgwal, E., & Gense, R. (2004). Driving style and traffic measures-influence on vehicle emissions and fuel consumption. *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering* 218(1), 43-50.

Acknowledgements

This document was produced through an interagency agreement with the California Air Resources Board with additional funding provided by the University of California Institute of Transportation Studies MultiCampus Research Program on Sustainable Transportation.