Impacts of Traffic Operations Strategies on Passenger Vehicle Use and Greenhouse Gas Emissions

Policy Brief

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Policy Description

Traffic operations strategies aim to reduce greenhouse gas (GHG) emissions by optimizing traffic speeds and smoothing traffic flow. Excessive GHG emissions are generated by vehicles traveling at very low speeds during congested conditions and at very high speeds during off-peak periods; optimal cruising speeds from the standpoint of minimizing GHG reductions are generally between 30 and 50 miles per hour depending on the vehicle and driving conditions. Stop-and-go driving related to traffic signals and traffic congestion also generates excessive GHG emissions relative to smooth traffic flow. Traffic operations strategies fall into three general categories: congestion management, speed control, and signal coordination (Table 1).

Table 1. Types of Traffic Operations Strategies

Strategy	Description	Methods
Congestion management on freeways	Shift low speed travel to optimal cruising speeds	Ramp metering, traffic incident management, and work zone management
Speed control on freeways	Shift high speed travel (over 65 mph) to optimal cruising speeds	Enforcement of speed limits (e.g., police, radar, camera, and aircraft)
Signal coordination on local streets and highways	Decrease travel at very low speeds and minimize number and duration of starts and stops (including accelerations, decelerations, and idling)	Signal timing optimization, with or without real-time data

Impacts of Traffic Operations Strategies

The studies included in this review assess the GHG effects of traffic operations strategies both in the U.S. and internationally. The effects are measured as the difference in total GHG emissions generated during a specified period of time on a roadway segment or corridor with and without the traffic operations strategy. The total impacts depend on the number and type of vehicles on the network segment that shift from traveling at very low and/or high speeds to optimal cruising speeds and/or reduce stop-and-start vehicle movements (accelerations, decelerations, and idling) for the specific time period. Congestion mitigation and traffic control strategies may also reduce traffic delay and thus induce additional vehicle travel, which may off-set emissions reductions.

Effect Size

The available evidence shows a range of effect sizes (Table 2). Traffic operations strategies have been shown to reduce GHG emissions during the time period on the roadway segment(s) where the strategy is implemented by around 7 percent for ramp metering, 4 percent for traffic incident management, 8 percent to 25 percent for speed limit enforcement, and 1 percent to 10 percent for signal coordination (Table 2). Fuel consumption has been shown to decline by 0.1 percent to 3.2 percent on a daily basis for traffic incident management programs.

Table 2. Impact of Traffic Operations Strategies on GHG Emissions

Study	Study Location	Results	
		Strategy	% Change in GHG
Bae et al. (2012)	Korea	Ramp metering	-7.3%
Fries et al. (2007)	South Carolina, U.S.	Traffic incident management	-3.2%*
Fries et al. (2012)	Greenville County, South Carolina, U.S.	Traffic incident management	-0.07% to -0.22%*
Avetisyan et al. (2014)	Montgomery County, Maryland, U.S.	Traffic incident management	-4%
Barth & Boriboonsomsin (2008)	Southern California, U.S.	Speed control	-8%
Madireddy et al. (2011)	Antwerp, Belgium	Speed control	-25%
Midenet et al. (2004)	Paris suburb, France	Signal coordination	-4%
Stevanovic et al. (2009)	Salt Lake City, Utah, U.S.	Signal coordination	-1%
Zhang et al. (2009)	Beijing, China	Signal coordination	-9%
Madireddy et al. (2011)	Antwerp, Belgium	Signal coordination	-10%

*Daily change in fuel consumption

The effect of traffic operation strategies on GHG emissions also depends on their effect on vehicle-miles of travel. Strategies that effectively increase facility capacity, including congestion management strategies and signal coordination, may lead to increased vehicle travel, which would at least in part off-set the estimated GHG reductions (Noland and Quddus, 2006; Bigazzi and Figliozzi, 2012). On the other hand, speed limit enforcement programs may increase average travel times, thereby discouraging vehicle travel; studies of these programs may thus under-estimate GHG reduction.

Evidence Quality

Ideally, the effects of traffic operations strategies would be evaluated using controlled field experiments in which emissions data were collected before and after the implementation of the strategy from vehicles using the affected roadway segment (the “treatment” site) and over a comparable roadway segment not affected by the implementation of the strategy (a “control” site). Such experiments are extremely challenging to design and expensive to implement (De Coensel et al., 2012).

Most studies in Table 2 use traffic models that simulate vehicle activity on the roadway segment(s) affected by the traffic operations strategy and emissions models to estimate the GHG emissions associated with that vehicle activity. Only two studies use vehicle activity data measured directly from the field rather than models (Barth and Boriboonsomsin, 2008; Midenet et al., 2004). Four studies adjust the emissions model to reflect the local vehicle fleet rather than the fleet for a larger geographic area (Madireddy et al., 2011; Stevanovic et al., 2009; Zhang et al., 2009; Avetisyan et al., 2014). The other studies rely on emissions rates for fleets for larger geographic areas.

None of the studies of signal coordination, traffic incident management, or ramp metering account for the possibility of induced travel. For this reason, they are likely to over-estimate the effect of these strategies on GHG emissions.

Caveats

The limited number of studies of each type of strategy, variations in methodology as described above, and variations in the applications studied with respect to both strategy design and context contribute to significant uncertainty as to the size of the effect of traffic operations strategies in any particular application. The effects of traffic operations strategies depend on the share of vehicles affected by the strategy, the types of vehicles affected, and baseline levels of congestion. Half of the studies are from outside the U.S., with only one from California. California tends to have a cleaner vehicle fleet than is typical in other areas of the U.S. and non-European countries. In addition, higher levels of congestion in metropolitan areas of California than elsewhere in the U.S. may mean higher levels of suppressed demand and thus a greater increase in travel in response to traffic operations strategies. Some hypothetical studies indicate that signal coordination methods may not be effective in locations with high levels of traffic or saturated traffic (Huang and Huang, 2003). The estimated effect sizes shown in Table 1 apply to specific geographic areas and time periods and may not be applicable to other areas or time periods.

Co-benefits

Traffic operations strategies may provide a cost-effective means to enhance existing roadway capacity and reduce some traffic delay, which in turn can lead to economic efficiency benefits. These strategies may also reduce fuel consumption and criteria pollutants. These strategies may also have safety benefits (in the form of avoided accidents) and reduce noise levels.

Examples

Several states have implemented traffic incident management policies.[1] The California Department of Transportation (DOT) and the California Highway Patrol have a goal of a 90 minute clearance time. Florida DOT and the Florida Highway Patrol must (by Florida's Open Roads Policy) clear incidents within 90 minutes of the arrival of the first responding officer. Washington DOT and the Washington State Patrol also have a 90-minute maximum clearance time goal.

Ramp metering has been implemented in many parts of California, including Los Angeles, San Diego, Sacramento, the San Francisco Bay Area, and Fresno.

Speed control has not been a popular approach in the U.S. The 55 mph speed limit imposed to conserve fuel during the 1970s oil crisis has been raised to 65 mph or higher on much of the nation’s freeway system, and enforcement of speed limits is inconsistent. Some states have experimented with variable speeds limits, a strategy implemented in the Netherlands, Germany, and Denmark to create more uniform travel speeds and improve traffic flow on freeways.[2] In this approach, called “speed harmonization” in Europe, speed limits are dynamically adjusted based on traffic levels. More consistent traffic speeds and smoother traffic flow have the potential to improve fuel efficiency and reduce GHG emissions (Mott MacDonald Ltd., 2008). Examples of signal coordination programs include the City of Denver, Colorado, where new signal timing plans are developed every 3 to 5 years for major corridors and new roadway

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[1] http://ntimc.transportation.org/Documents/InstitutionalModels.pdf
[2] http://ops.fhwa.dot.gov/publications/fhwahop10031/sec3.htm

projects; and the City of Philadelphia, Pennsylvania, where the city works with two towns, Upper Darby and Springfield, to implement arterial signal coordination across jurisdictional boundaries.[3]

[3] http://ops.fhwa.dot.gov/publications/fhwahop08024/fhwa_hop_08_024.pdf

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