# Impacts of Bicycling Strategies on Passenger Vehicle Use and Greenhouse Gas Emissions

## Policy Brief

**Susan Handy and Gil Tal, University of California, Davis**
**Marlon G. Boarnet, University of Southern California**

**September 30, 2014**

Policy Brief: http://www.arb.ca.gov/cc/sb375/policies/bicycling/bicycling_brief.pdf

Technical Background Document:
http://www.arb.ca.gov/cc/sb375/policies/bicycling/bicycling_bkgd.pdf

California Environmental Protection Agency
Air Resources Board

**Policy Brief on the Impacts of Bicycling Strategies on Passenger Vehicle Use and Greenhouse Gas Emissions**

Susan Handy and Gil Tal, University of California, Davis
Marlon G. Boarnet, University of Southern California

## Policy Description

Strategies that facilitate increased bicycle use have the potential to reduce vehicle trips and vehicle miles traveled (VMT) by shifting trips from cars to bicycles and even from cars to transit. Bicycling strategies fall into two main categories: (1) infrastructure projects that improve bicycle accessibility, safety, and convenience, either while traveling or at the end of the trip, and (2) programs that promote bicycling directly or indirectly through education, community events, advertising, and other activities (Table 1). Several strategies are used to facilitate bicycling in combination with transit. Legal policies, such as helmets and speed limits, may also affect bicycling levels. Communities have implemented projects, programs, and policies separately and in combination. Comprehensive efforts that involve complementary strategies are generally guided by a local or regional bicycle plan.

*Table 1. Strategies to Increase the Level of Bicycling in Communities*

| Category | Examples | |
|---|---|---|
| Infrastructure – travel related | On-road bicycle lanes<br>Two-way travel on one-way streets<br>Shared bus/bike lanes<br>Off-street bike paths<br>Signed-bicycle routes<br>Bicycle boulevards<br>Cycletracks (bike lanes physically separated from traffic lanes)<br>Colored lanes<br>Shared lane markings<br>Bike boxes (marked spaces reserved for bicyclists in front of traffic lanes at signals) | Traffic signal phases for bicyclists<br>Facility maintenance programs<br>Way-finding signage<br>Cut-throughs and short-cuts<br>Traffic calming<br>Home zones (residential streets designated as play areas with 10mph speed limits)<br>Car-free zones<br>Complete streets policies (establish equal priority for non-auto modes) |
| Infrastructure – trip end | Bike parking – general, sheltered, guarded<br>Bike lockers | Showers at work places<br>Bike stations |
| Programs – bicycle specific | Bike to Work days<br>Cyclovias (community events during which streets are temporarily closed to automobiles)<br>Other bicycle promotions | Education/training<br>Bike sharing programs<br>Other bicycle access programs |
| Programs – general travel | Trip reduction programs<br>Individualized marketing | Travel awareness programs<br>Safe Routes to School programs |
| Integration with transit | Parking at rail stations<br>Parking at bus stops<br>Bike racks on buses | Bikes on rail cars<br>Short-term rental bikes |
| Legal policies | Helmet laws<br>Speed limits | |

Source: Pucher, et al. 2010. For more details regarding these strategies, including definitions, please see: http://www.bicyclinginfo.org/index.cfm

## Impacts of Bicycle Strategies

Bicycling has an impact on VMT when a bicycle trip replaces a driving trip. In most cases, bicycling for utilitarian purposes (i.e. as a mode of travel to a destination) will have an impact on VMT, but bicycling for recreational purposes only will not. Bicycling for either purpose will have an impact on VMT only if it replaces travel by car.

*Effect size*

We identified no studies that provide direct evidence of the impact of bicycle strategies on VMT. In fact, relatively few studies even provide direct evidence of the impact of bicycle strategies on bicycling (Pucher, et al. 2010). Most of these studies measure only the impact on bicycling in general, including both recreational and utilitarian bicycling, though some focus specifically on commuting by bicycle. Bicycling is usually measured in one of two ways: bicycle share, measured as share of trips or share of workers, or bicycle counts, measured as the number of bicyclists observed at a particular point. The effect sizes presented below were calculated from results presented in the cited papers, as described in the accompanying background memo.

- Infrastructure Projects

Evidence on the impact of infrastructure projects was thoroughly reviewed in Pucher, et al. (2010). Two studies from that review, plus one more recent study, provide evidence of the impact of infrastructure on bicycling that can be reported as an effect size (Table 2). Because the methods and measures are different, the results are not directly comparable. We therefore do not recommend a specific value for the effect size based on these results, but do note that all three studies show that infrastructure investments significantly increase bicycling, and two show that they decrease driving.

*Table 2: Infrastructure Impact on Bicycle Use*

| Study | Study Location | Study Year | Results | | |
|---|---|---|---|---|---|
| | | | *Infrastructure Variable* | *Mode Variable* | *Change in Mode Variable for 1% Increase in Infrastructure Variable* |
| **Marshall and Garrick (2010)** | 24 medium-sized California Cities | 2000 | Percent of citywide street length with bike lanes | % commuting by bicycle | 0.35% to 0.36% |
| | | | | % commuting by driving | -0.004% to -0.010% |
| **Dill and Carr (2003)** | 33 large US cities | 2000 | Miles of on-street bike lanes per square mile | % commuting by bicycle | 0.32% |
| | | | Average state spending of federal funds per capita on bicycle and pedestrian infrastructure | % commuting by bicycle | 0.32% |
| **Noland and Kunreuther (1995)** | Philadelphia metro area | 1991 | Perceived bicycle parking availability | Probability of bicycling | 0.83% |
| | | | | Probability of using automobile | -0.01% |
| | | | Perceived bicycle comfort | Probability of bicycling | 0.97% |
| | | | Perceived bicycle convenience | Probability of bicycling | 3.16% |
| | | | | Probability of using automobile | -0.02% |

Marshall and Garrick (2010) examined the association between street network characteristics and share of commuting by mode for 24 medium-sized cities in California. A 1 percent increase in the percent of citywide street length with bike lanes was associated with an increase in the share of workers commuting by bicycle of 0.35

to 0.36 percent and with a decrease in the share of workers commuting by driving of 0.004 percent to 0.010 percent. The estimated impacts vary slightly depending on the structure of the street network.

For a sample of 33 of the largest cities across the U.S., results from Dill and Carr (2003) show that a 1 percent increase in either the miles of bicycle lanes per square mile or the state's average spending of federal funds on bicycle and pedestrian infrastructure per capita was associated with a 0.32 percent increase in the share of workers in the city commuting by bicycle. If the initial share of bicycle commuters is 1 percent, the share would increase to 1.0032 percent. With a 100 percent increase in bicycle lanes per square mile, or average spending, the share would increase to 1.32 percent.

Noland and Kunreuther (1995) examined choice of commute mode for a sample of Philadelphia residents and estimated the direct and indirect effects of bicycle infrastructure, on both increasing the probability of bicycling and decreasing the probability of driving. A 1 percent increase in perceived bicycle parking availability was associated with a 0.83 percent increase in the probability of bicycling, but only a 0.01 percent decrease in the probability of driving. Perceived bicycling convenience (measured on a 7-point scale from "very inconvenient" to "very convenient") and perceived bicycling comfort (measurement scale is not reported in the paper), both influenced by bicycle infrastructure, had larger effects on the probability of bicycling, though again the effect on the probability of driving was much smaller.

In the aggregate, the authors estimated that building a network of bicycle lanes so that no commuter is exposed to the risk of riding on a road without shoulders would increase bike mode share by 196 percent in the short-term and 754 percent in the long-term (from a very low starting base of 0.04 percent), and reduce the driving share by 1.7 percent in the short-term and 30.4 percent in the long-term (from a starting base of 76.7 percent); the short-term was defined in this study as a period of time in which no additional mode options are available to individuals, while the long-term was defined as a period of time in which all mode options become available to all individuals.

In addition to these studies, a recent study by Buehler (2012) examines the effect of bicycle infrastructure on the probability of bicycling to work in Washington, DC. This study shows that for each additional mile of bike lanes and paths per 1000 population, the odds that a worker commutes by bicycle increase by a factor of 1.11 relative to the odds of not commuting by bicycle. If the workplace provides bike parking, the odds of bicycle commuting are 1.78 times the odds of not bicycle commuting, and if the workplace provides bike parking as well as showers and lockers, the odds are 4.86 times higher.

- Promotional Programs

Programs to promote bicycling have rarely been rigorously evaluated for their impact on numbers of bicyclists (Pucher, et al. 2010). In the few studies available, variation in methods and measures makes comparisons difficult (Table 3). Nevertheless, these programs seem to have a measurable and meaningful positive effect on bicycling.

Given the limited number of studies and differences in the programs they evaluate, we do not recommend a specific value for the effect size.

*Table 3: Impact of Promotional Programs on Bicycle Use*

| Study | Study Location | Study Year(s) | Results | | |
|---|---|---|---|---|---|
| | | | *Program* | *Bicycling measure* | *Effect size* |
| **Johnson and Margolis (2013)** | London | 2010-2011 | Adult training program | Average number of days cycled to work in the last week for participants | + 101% three months after first training session |
| **League of American Bicyclists (2008)** | San Francisco, CA | 2008 | Bike to Work Day (BTWD) promotion | Bicycle counts at central street intersection | +100% on BTWD; +25.4% four weeks later |
| **Cooper (2007)** | King County, WA | 2006 | Promotion of transit and non-motorized modes to individuals who commit to reduce driving for 10 weeks | Bicycle trips that replace drive alone trips | 0.4 trips per household |
| **Staunton et al. (2003)** | Marin County, CA | 2002-2003 | Safe Routes to School program | Number of children bicycling to school | +114% |

Other evidence suggests upper bounds for the total effect that could be expected from bicycle strategies. Pucher, et al. (2010) examined trends in cities world-wide that have adopted comprehensive programs involving infrastructure improvements and promotional programs, and reported increases in bicycling share as shown in Table 3. A study in the U.K. of cities that implemented comprehensive bicycling initiatives, including infrastructure investments and promotional programs, found that bicycling to work increased from 5.8 percent in 2001 to 6.8 percent in 2011, an increase of 1.0 percentage points, compared to an increase of 0.3 percentage points in similar cities that did not implement such programs (Goodman et al., 2013).

*Table 3: Long-Term Increases in Bicycling Share for Comprehensive Programs*

| City | Bicycling Share at Start of Program | Number of Years After Start of Program | Increase in Bicycling Share |
|---|---|---|---|
| Barcelona | 0.7% | 2 | 135% |
| Paris | 1.0% | 6 | 150% |
| Bogota | 0.8% | 8 | 300% |
| Portland | 1.1% | 18 | 445% |
| Boulder | 3.8% | 26 | 132% |

Source: Pucher, et al. 2010

*Evidence Quality*

These studies are among the few available that quantify the effect of bicycle projects, programs, and policies on utilitarian bicycling, specifically. The two studies on the effects of infrastructure use cross-sectional designs that compare bicycling in areas with different levels of infrastructure. The effect of infrastructure on bicycling at the city level as estimated by Dill and Carr (2003) may differ from the effect for individuals. These studies do not account for self-selection, that is, the possibility that bicycling-inclined individuals choose residential locations with better bicycle infrastructure. No studies were identified that directly estimate the effect of infrastructure by measuring bicycling before and after the completion of an infrastructure project. The studies of the promotional programs do use before-and-after measurements of bicycling but do not carefully control for other factors that might affect bicycling. They also do not account for the possibility that programs are more likely to be adopted in areas with greater potential for increased bicycling. While these limitations make it impossible to identify an accurate range of effect sizes, it is worth noting that all studies show a positive, non-zero effect on bicycling.

*Caveats*

The applicability of the estimated effect sizes may be limited. Two of the studies cited here are based on data that are at least 10 years old. It is possible that effect sizes have increased as the popularity of bicycling has increased in recent years; they could also have decreased if individuals most susceptible to these strategies have already increased their bicycling. In addition, all studies cited here focus on metropolitan regions as a whole, or on the urban core or suburban areas within those regions. The effect sizes are likely to be smaller for rural areas where destinations are farther apart.

In most communities, bicycling represents a very small share of all daily travel, so that even large percentage increases in bicycling may lead to small percentage decreases in driving, as seen in the Philadelphia study (Noland and Kunreuther, 1995). Furthermore, some new bicycling trips may replace trips by transit or walking rather than driving.

While studies so far have shown small impacts from individual strategies, evidence suggests that a comprehensive strategy involving infrastructure, promotional programs, and other policies has the potential to significantly increase bicycling (Pucher, et al. 2010). Although most cities that have succeeded in increasing bicycling are found outside the U.S. (e.g. Copenhagen, Amsterdam, Barcelona, Bogota), Boulder, CO and Portland, OR have had similar success, as described below.

**Greenhouse Gas Emissions**

No studies provide direct evidence of the impact of bicycling strategies on greenhouse gas (GHG) emissions. Translating bicycling increases into GHG emissions reductions requires two steps: translating increases in bicycling into reductions in VMT, and converting reductions in VMT into reductions in GHG emissions. An increase in bicycle trips does not necessarily translate into a 1-to-1 decrease in vehicle trips, depending on whether bicycle trips are made instead of, or in addition to, driving trips (Krizek, et al. 2009). The resulting reduction in GHG emissions also depends on the nature of the VMT eliminated (e.g. speeds, acceleration, deceleration, times vehicle is started) and the types of vehicles owned by individuals who switch from driving to bicycling.

**Co-benefits**

Bicycling strategies have the potential to produce many important co-benefits, particularly with respect to health. Bicycling as a mode of transportation represents an important source of physical activity, critical in the battle against obesity, cardio-vascular disease, and other pressing health problems. Bicycling is also a relatively affordable means of transportation that can help to fill the gap between areas reachable by walking and those reachable by transit, thereby increasing access to jobs and other important activities for lower income households. Strategies such as traffic calming and complete streets policies may help to improve safety and livability for all residents of a community, not just bicyclists. Investments in bicycle facilities, particularly off-street bicycle paths, may increase property values and promote economic development (Lindsey et al., 2004; Clifton et al., 2013).

**Examples**

Portland, OR has seen a dramatic increase in bicycling in recent years (Pucher, et al. 2010). The share of workers commuting by bicycle rose from 1.1 percent in 1990 to 1.8 percent in 2000 and 6.0 percent in 2008. The number of workers commuting by bicycle increased 608 percent from 1990 to 2008, while the number of workers increased only 36 percent. The number of bicycles crossing four bridges into downtown increased 369 percent from 1992 to 2008, while the number of reported crashes in the city increased only 14 percent over the same period. Portland achieved these increases through a variety of strategies. Infrastructure investments produced a 247 percent increase in miles of bikeways (including lanes, paths, and boulevards). The city implemented innovative ideas from Europe, including colored bicycle lanes in places with high potential for bicycle-car conflict and bicycle “boxes” that put bicyclists ahead of cars when waiting for left-turns. The city also invested in on-street bicycle parking "corrals," and the transit agency installed bicycle racks on all buses. Promotional activities include "Bike Sundays," when city streets in selected neighborhoods are closed to vehicle traffic, as well as other educational and marketing activities.

## References

Buehler, R. (2012). Determinants of bicycle commuting in the Washington, DC region: The role of bicycle parking, cyclist showers, and free car parking at work. *Transportation Research Part D*, 17, 525-531.

Clifton, K.J., Muhs, C., Morrissey, S., Morrissey, T., Currans, K., and Ritter, C. (2013). Examining Consumer Behavior and Travel Choices. Final Report OTREC-RR-12-15, Oregon Transportation Research and Education Consortium, Portland, OR, February.

Cooper, C. (2007). Successfully changing individual travel behavior: Applying community-based social marketing to travel choice. *Transportation Research Record* 2021: 89-99.

Dill, J., Carr, T. (2003). Bicycle commuting and facilities in major U.S. cities: If you build them, commuters will use them. *Transportation Research Record* 1828, 116–123.

Goodman, A., Panter, J., Sharp, S.J., & Ogilvie, D. (2013). Effectiveness and equity impacts of town-wide cycling initiatives in England: A longitudinal, controlled natural experimental study. *Social Science & Medicine* 97, 228-237.

Johnson, R. & Margolis, S. (2013). A review of the effectiveness of adult cycle training in Tower Hamlets, London. *Transport Policy* 30, 254-261.

Krizek, K., Handy, S. and Forsyth, A. (2009). Explaining Changes in Walking and Bicycling Behavior: Challenges for Transportation Research. *Environment and Planning B* 36: 725-740.

League of American Bicyclists (2008). Bike to Work events in selected US Cities. Unpublished memo. Washington, DC.

Lindsey, G., Man, J., Payton, S., and Dickson, K. (2004). Property Values, Recreation Values, and Urban Greenways. Journal of Park & Recreation Administration, 22(3), 69-90.

Marshall, W.E. & N.W. Garrick. (2010). Effect of Street Network Design on Walking and Biking. *Transportation Research Record*. 2198: 103-115.

Noland, R. and Kunreuther, H. (1995). Short-run and long-run policies for increasing bicycle transportation for daily commuter trips. *Transportation Policy* 2(1): 67–79.

Pucher, J., Dill, J. and Handy, S. (2010). Infrastructure, programs, and policies to increase bicycling: An international review. *Preventive Medicine* 50: 106–125. Available: http://policy.rutgers.edu/faculty/pucher/Pucher_Dill_Handy10.pdf

Staunton, C.E., Hubsmith, D., and Kallins, W., (2003). Promoting safe walking and biking to school: The Marin County success story. *American Journal of Public Health* 93: 1431–1434.

## Acknowledgments

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 and the William and Flora Hewlett Foundation.