CLIMATE-SMART CITIES™

Methodology for assessing the benefits of active transportation projects

EXECUTIVE SUMMARY

THE TRUST FOR PUBLIC LAND

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The Trust for Public Land creates parks and protects land for people, ensuring healthy, livable communities for generations to come.

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1 Introduction

PEOPLE IN CITIES CAN WALK or take public transportation instead of driving, and generally live in more compact, energy-efficient housing than people in suburbs, so making cities more livable to attract the next generation of urbanites is a key strategy in fighting climate change. At the same time, cities are also uniquely vulnerable to the effects of climate change. Paved landscapes can create a "heat island" that amplifies high temperatures, and critical infrastructure gaps can put large numbers of people at risk during extreme weather events. The Trust for Public Land (TPL) Climate-Smart Cities initiative helps cities mitigate and adapt to climate change through conservation and design through four strategies:

- **CONNECT:** creating better bicycle and pedestrian networks helps people ditch driving, reducing carbon emissions and improving health.
- **COOL:** increasing green space such as parks, tree canopies, and gardens helps to cool the urban landscape, reducing the health impacts of heat waves for everyone, particularly older adults, low-income households, and other vulnerable residents.
- **ABSORB:** replacing pavement with permeable surfaces or swales helps to filter and absorb rainfall, reducing water treatment costs and preventing pollution.
- **PROTECT:** placing well-designed parks and green space where they can act as natural buffers to rising seas and storm surges protects surrounding neighborhoods while providing opportunities for people to get outdoors.

In order to help cities become better connected, the TPL Climate-Smart Cities team has been working with cities to plan comprehensive trail networks that allow people to reach destinations by bike and foot safely and conveniently. For example, In Kirkland, Washington, TPL staff collaborated with several county and city agencies to design connector trails that feed into the Eastside Rail Corridor, a 42-mile former rail line that is envisioned as the spine of a major active transportation network.

This work includes analyzing and communicating the climate benefits of different trails to arrive at a climate-smart solution. TPL developed a methodology in 2007 to quantify greenhouse gas reductions due to bicycle and pedestrian facilities, and pilot tested this methodology on Connect projects. This report describes an update to the methodology to align it with the state of the practice in transportation planning, incorporate lessons learned from TPL's experience to date, and quantify additional environmental, economic, and public health benefits.

1.1 Benefits of bicycle and pedestrian trails

Bicycle and pedestrian trails can make it safer, more convenient, and more pleasant for people to bike and walk instead of driving. Research has found that the majority of travelers are interested in bicycling more but are concerned about being hit by motor vehicles.[1] Since people most often take short trips by bicycle and foot, trails that provide a direct, safe connection to destinations make cycling and walking more viable alternatives to driving. Bicyclists and pedestrians are more sensitive to their surroundings than other travelers, so trails that travel through pleasant natural settings can also induce people to bicycle and walk more. In addition, many people access transit stations by foot or by bicycle, so connecting trails to transit can also encourage people to ride the bus or train.

By making it easier for people to walk, bicycle, or take transit instead of driving, trails produce a host of benefits:

- **ECONOMIC BENEFITS** Transportation is the second-largest household expenditure after housing, and people save money by driving less. Businesses that are accessible by bicycle or foot often see more shoppers, and increased bicycling helps to boost spending at local bicycle-related businesses. Homeowners who live near trails may see an increase in property values, with a corresponding increase in property tax revenues for local governments. Communities that develop a reputation for being walkable or bike-friendly may also see increased tourism from active travelers.[2]
- **ENVIRONMENTAL BENEFITS** People who drive less reduce air pollution and greenhouse gas emissions. Over the long term, cities where people drive less need less space for roads and parking, which helps to preserve open space and reduce water pollution due to runoff from paved surfaces.
- **HEALTH BENEFITS** People who bike and walk every day are more likely to meet physical activity guidelines, which helps to reduce the risk of diabetes, obesity, and other related health issues. Meanwhile, long car commutes can increase stress and contribute to a sedentary lifestyle. Communities where people drive more generally see a higher incidence of collisions, and bicyclists and pedestrians are particularly vulnerable to injury and death from traffic incidents, so trails can help reduce the extent and severity of collisions. Reducing air pollution also lowers the incidence of asthma and other respiratory conditions. Shifting travel from driving to bicycling or walking not only benefits individuals, but reduces overall public health care costs.[3]
- **SOCIAL EQUITY BENEFITS** Trails benefit everyone, but particularly low-income people, who are less likely to own cars and more likely to walk or bicycle out of need instead of choice. Low-income and minority communities have disproportionately high exposure rates to unsafe streets and traffic collisions, so providing trails in these communities can have significant safety benefits. Many low-income neighborhoods lack grocery stores or other neighborhood businesses, and well-planned trails can improve residents' access to healthy food, health and social services, and other important destinations. Some of these benefits can be quantified. For more than a decade, transportation agencies have been estimating reductions in vehicle trips

and vehicle miles traveled due to bicycle facilities in order to calculate the resulting reduction in air pollution. Over time, researchers and transportation planners have refined methods for estimating the impact of bicycle and pedestrian facilities on driving. At the same time, research, tools, and best practices have also become available to quantify some of the other economic, environmental, and health benefits of reduced driving and increased active transportation.

1.2 Quantifying benefits

The methodology described in this report and the accompanying spreadsheet tool draw on state-of-the-practice research and methods to quantify the benefits of bicycle and pedestrian trails, including:

- Reduced greenhouse gas emissions
- Reduced air pollution
- Household transportation savings
- Reduced mortality

At the heart of our methodology is a method for estimating reductions in vehicle trips and vehicle miles traveled due to bicycle facilities that was developed by the California Air Resources Board (ARB) in 2005.[4] There are other methods available to estimate the transportation impacts of bicycle and pedestrian facilities, but the ARB methodology combines several key advantages:

- **IT IS WIDELY USED** Transportation agencies throughout the United States continue to apply and improve upon the methodology developed by ARB. Most recently, regional transportation agencies in the Phoenix[5] and Atlanta[6] metropolitan areas have developed applications of the methodology that account for pedestrian trips and for increased transit trips where trails connect to transit stations. Applying the ARB methodology helps to ensure that TPL's work represents the state of the practice.
- **IT IS SIMPLE** The calculations and assumptions for the ARB methodology can be encapsulated in a spreadsheet, and the methodology draws upon data that are typically available from local transportation agencies. The *Benefit-Cost Analysis of Bicycle Facilities* developed by researchers at the University of Minnesota, which is the next simplest nationally applicable methodology, requires GIS analysis to identify the number of residents living near a planned facility.[7] More sophisticated methodologies used by regional transportation agencies require complex travel demand models to analyze bicycle and pedestrian behavior.[8]

- **IT IS WIDELY APPLICABLE** The ARB methodology is based primarily on national data and has been applied by transportation agencies throughout the United States Local and regional transportation agencies have developed methods that may capture the behavior of local bicyclists and pedestrians more accurately but draw on extensive data, including travel surveys, traffic counts, and spatial data on the transportation network.[9] Since TPL advocates for high-quality trails in communities across the United States, we need to use a methodology that is broadly applicable and does not require extensive data collection.

The methodology described here is broader in focus than the ARB methodology. It converts reduced vehicle trips and vehicle miles traveled due to bicycle and pedestrian trails not only to reductions in greenhouse gas emissions and air pollutants, but also to household transportation cost savings. The methodology avoided deaths using factors drawn from best practices and peer-reviewed research. Wherever possible, we use factors that are recommended by federal agencies, including the Environmental Protection Agency and the Internal Revenue Service.

2 Methodology

2.1 Overview

THE ARB METHODOLOGY, which was developed for the purpose of quantifying emissions reductions when allocating federal Congestion Mitigation and Air Quality (CMAQ) funds, assumes that a new bicycle facility leads a portion of drivers who travel along the route served by the facility to shift from driving to bicycling. It calculates two key outputs, reduced vehicle trips and vehicle miles traveled (VMT), based on the characteristics of the route and of the surrounding area. These outputs are often converted into emissions reductions for the purpose of allocating CMAQ funding and comparing the environmental benefits of trails to those of other transportation projects, but they can also serve as a basis for calculating economic and public health benefits.

Several metropolitan planning organizations (MPOs) have applied the ARB methodology when allocating CMAQ funding, and a few have added updates that we incorporate into our methodology. Whereas the ARB methodology focused exclusively on bicycling, the Maricopa Association of Governments (MAG) assumes that trails also induce a shift from driving to walking and uses the same calculations to quantify reduced vehicle trips due to walking as for bicycling.[10] The Atlanta Regional Commission (ARC) incorporates this assumption and also captures mode shift to transit for trails that connect to stations.[11]

2.2 Calculations

2.2.1 REDUCED VEHICLE TRIPS DUE TO BICYCLING AND WALKING

To calculate the reduction in vehicle trips due to a bicycle or pedestrian project, the methodology applies an adjustment factor and activity center credit to the daily traffic volume along a parallel arterial in order to estimate the number of drivers who shift to bicycling or walking and annualizes the result, as follows:

$$VT_{B,P} = (BIKE \times D \times AADT \times [A + C]) + (PED \times D \times AADT \times [A + C])$$

Where:

$VT_{B,P}$ = Annual vehicle trips reduced due to bicycling and walking

BIKE = Binary variable indicating whether the project has a bicycle component

PED = Binary variable indicating whether the project has a pedestrian component

D = Number of days per year that people use the facility

AADT = Annual average daily traffic on a parallel roadway

A = Adjustment factor (based on AADT, facility length, and whether the project is located in a university area; see Table 1)

C = Activity center credit (based on the number of activity centers located within a quarter- or half-mile of the project; see Table 2)

Table 1 and Table 2 summarize the adjustment factors and activity center credits used in the methodology.

TABLE 1: ADJUSTMENT FACTORS (A) BY AADT, FACILITY LENGTH, AND WHETHER THE PROJECT IS LOCATED IN A UNIVERSITY AREA

AADT on parallel roadway	Facility length (mi)		
	<1	1-2	>2
NON-UNIVERSITY AREA			
12,000	0.0019	0.0029	0.0038
24,000	0.0014	0.002	0.0027
30,000	0.001	0.0014	0.0019
UNIVERSITY AREA			
12,000	0.0104	0.0155	0.0207
24,000	0.0073	0.0109	0.0145
30,000	0.0052	0.0078	0.0104

TABLE 2: ACTIVITY CENTER CREDITS (C) BY NUMBER OF ACTIVITY CENTERS AND DISTANCE FROM THE FACILITY

Number of activity centers	Within 1/2 mile of the facility	Within 1/4 mile of the facility
<3	0	0
3	0.0005	0.001
4-6	0.001	0.002
>6	0.0015	0.003

2.2.2 REDUCED VEHICLE TRIPS DUE TO TRANSIT

The methodology calculates the reduction in vehicle trips due to transit by applying a factor that estimates the increase in transit use due to new trail connections to the number of transit boardings at stations served by the trail and annualizing the result, as follows:

VT_T = TRANS x D x B x T

Where:

VT_T = Annual auto trips reduced due to new transit trips

TRANS = Binary variable indicating whether the project provides direct access to transit

D = Number of days per year that people use the facility

B = Daily transit boardings at stations served by the project

T = Increase in transit trips (based on the area type and transit type; see Table 3)

TABLE 3: INCREASE IN TRANSIT TRIPS (T) BY AREA TYPE AND TRANSIT TYPE

Area type	Non-fixed guideway	Fixed guideway
Central Business District	2.0%	4.0%
Urban	2.0%	4.0%
Suburban	1.6%	3.2%
Difficult Terrain	1.4%	2.8%

2.2.3 REDUCED VMT

The methodology calculates reduced vehicle miles traveled (VMT) by multiplying the number of trips shifted to bicycling, walking, and transit by the average trip lengths for each mode:

$$VMT = VT_B * L_B + VT_P * L_P + VT_T * L_T$$

Where:

VMT = Annual VMT reduced

VT_B = Annual vehicle trip reductions due to bicycling

L_B = Average length of bicycle trips

VT_P = Annual vehicle trip reductions due to walking

L_P = Average length of pedestrian trips

VT_T = Annual vehicle trip reductions due to transit

L_T = Average length of transit trips

The methodology estimates the environmental, economic, and public health benefits of trails based on the number of vehicle trips and VMT reduced.

2.3 Variables

The calculations involved in the methodology are relatively straightforward, but it can be challenging to keep track of the many variables at play. Table 4 summarizes the inputs and constants used in the tool, including the abbreviations used in the equations shown above (where applicable); the primary data source; and notes with additional detail on each variable or information on how the variable is used. The values for each constant are available in the Constants tab of the spreadsheet tool.

TABLE 4: SUMMARY OF VARIABLES USED IN THE METHODOLOGY			
INPUTS			
Abbrev.	**Variable**	**Source**	**Notes**
	Scenario year	Project information	Enter the year in which the project will be completed; used to look up emission factors.
AADT	Annual average daily traffic on a parallel roadway (vehicles per day, both directions)	Local/regional transportation agency	Used as a proxy for demand along the bike/ped route and to determine adjustment factor (A). Not to exceed 30,000 vehicles per day; see Section 3.1.
	Length of bicycle/ pedestrian project (miles)	Project information	Used to determine adjustment factor (A).
	Number of activity centers within a quarter mile of the project	Online mapping tool	Activity centers include banks, churches, health-care centers, transit stations, offices, post offices, public libraries, shopping areas, grocery stores, and colleges, as well as other significant destinations. Used to determine activity center credits (C); see Section 3.4.
	Number of activity centers within a half mile of the project	Online mapping tool	Activity centers include banks, churches, health-care centers, transit stations, offices, post offices, public libraries, shopping areas, grocery stores, and colleges, as well as other significant destinations. Used to determine activity center credits (C); see Section 3.4.
	Is the project located in a university area?	User discretion	Enter "yes" if the project is located in a university town with <250,000 population, has a combined walk/bike commute mode share that is comparable to local university areas, or is greater than 6.2%. Used to determine adjustment factor (A); see Section 3.3.
	Number of days per year that people use the facility	Local/regional transportation agency or default	Default assumption (250 days/year) comes from existing practice; see Section 3.6.
BIKE	Does the project have a bicycle component?	Project information	Enter "yes" if bicycles will be allowed on the facility.

INPUTS			
Abbrev.	**Variable**	**Source**	**Notes**
L_B	Average length of one-way bicycle trips (miles)	Local/regional transportation agency or default	Enter the average length of utilitarian (non-recreational) bicycle trips. Default assumption (2.27 miles) comes from the National Household Travel Survey; see Section 3.2.
PED	Does the project have a pedestrian component?	Project information	Enter "yes" if pedestrians will be allowed on the facility.
L_P	Average length of one-way pedestrian trips (miles)	Local/regional transportation agency or default	Enter the average length of utilitarian (non-recreational) bicycle trips. Default assumption (0.63 miles) comes from the National Household Travel Survey; see Section 3.2.
TRANS	Does the project provide direct access to transit?	Project information	Enter "yes" if the facility connects directly to a transit station; see Section 3.5.
	Does the project connect to fixed-guideway transit?	Project information	Enter "yes" if the facility connects directly to a rail or bus rapid transit station. Used to determine increase in transit trips (T); see Section 3.5.
	Area type (central business district, urban, suburban, difficult terrain)	User discretion	Used to determine increase in transit trips (T); see Section 3.5.
L_T	Average length of one-way transit trips (miles)	Local/regional transportation agency or default	Enter the average length of transit trips. Default assumption (8.54 miles) comes from the National Household Travel Survey; see Section 3.2.
B	Daily transit boardings at stations served by the project	Local transit agency	Sum-average daily transit boardings for all stops and stations served by the facility. Used to estimate additional transit trips; see Section 3.5.

CONSTANTS			
Abbrev.	**Variable**	**Source**	**Notes**
C	Activity center credit	ARB methodology	Based on AADT, facility length, and university area; see Section 3.4.
A	Adjustment factor	ARB methodology	Based on number of activity centers within a quarter and half mile; see Section 3.4.
	Bike/ped mode shift factor	Calculation	Sum of activity center credit and adjustment factor.
T	Increase in transit trips	ARC CMAQ Calculator	Based on whether connecting transit is fixed-guideway and area type; see Section 3.5.
SEF/ REF	Starting emission factors for CO_2e, PM, NO_x, and VOC (g/start)	EPA MOVES 2014a	Used to convert reduced vehicle trips and VMT to pollutant reductions; see Section 4.1.
SEF/ REF	Running emission factors for CO_2e, PM, NO_x, and VOC (g/mi)	EPA MOVES 2014a	Used to convert reduced vehicle trips and VMT to pollutant reductions; see Section 4.1.
I	IRS standard mileage rate ($2014/mi)	IRS	Used to convert reduced VMT to reduced transportation costs; see Section 4.2.
	Average annual household transportation costs	Bureau of Labor Statistics	Used to estimate percentage reduction in household transportation costs; see Section 4.2.
	New project users	Calculation	Based on trips reduced and used to estimate per household cost savings; see Section 4.2.
S	Average bicycling and walking speed (mph)	WHO HEAT Methodology	Used to determine weekly time spent bicycling and walking, which is a factor in estimating reduction in mortality risk; see Section 4.3.
	Amount of physical activity for project users (min/week)	Calculation	Used to determine reduction in mortality risk due to bicycling and walking; see Section 4.3.
V	Reference volume of physical activity (min/ week)	WHO HEAT Methodology	Used to determine reduction in mortality risk due to bicycling and walking; see Section 4.3.

CONSTANTS			
Abbrev.	**Variable**	**Source**	**Notes**
RR	Relative mortality risk associated with reference volume	WHO HEAT Methodology	Used to determine reduction in mortality risk due to bicycling and walking; see Section 4.3.
	Maximum reduction in mortality risk allowed	WHO HEAT Methodology	Used to determine reduction in mortality risk due to bicycling and walking; see Section 4.3.
	Reduction in mortality risk associated with increased walking/ cycling	Calculation	Used to estimate reduced deaths; see Section 4.3.
U	New project users	Calculation	Based on trips reduced and used to estimate reduced deaths; see Section 4.3.
MR	Mortality rate (deaths/100,000 people/yr)	CDC	Used to estimate reduced deaths; see Section 4.3.
VSL	Value of a statistical life ($2014)	US DOT	Used to monetize reduced deaths; see Section 4.3.

References

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2 For a summary of the economic benefits of bicycle infrastructure, see Flusche, D., *Bicycling Means Business: The Economic Benefits of Bicycle Infrastructure*, July 2012, http://www.advocacyadvance.org/site_images/content/Final_Econ_Update%28small%29.pdf.

3 For a summary of the health benefits of bicycling and walking, see FHWA Pedestrian and Bicycle Information Center, "Health Benefits of Biking and Walking," http://www.pedbikeinfo.org/data/factsheet_health.cfm.

4 California Air Resources Board, *Methods to Find the Cost-Effectiveness of Funding Air Quality Projects*, May 2005, http://www.arb.ca.gov/planning/tsaq/eval/eval.htm.

5 Maricopa Association of Governments, *Methodologies for Evaluating Congestion Mitigation and Air Quality Improvement Projects*, September 30, 2011, https://www.azmag.gov/Documents/CMAQ_2011-04-05_Final-CMAQ-Methodologies_3-31-2011.pdf.

6 Atlanta Regional Commission, *Emissions Calculator Technical Documentation and User Guide*, August 27, 2014: Section 5.2, Regional Bike/Pedestrian Projects, http://atlantaregional.com/File%20Library/Environment/Air/ARC-CMAQ-Calculator-Documentation.pdf.

7 Active Communities / Transportation Research Group, *Benefit-Cost Analysis of Bicycle Facilities*, http://www.pedbikeinfo.org/bikecost/.

8 For a summary of bicycle/pedestrian modeling approaches, see Kuzmyak, R., et al. 2014, *Estimating Bicycling and Walking for Planning and Project Development: A Guidebook.* National Cooperative Research Program Report 770. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_770.pdf.

9 Ibid.

10 Maricopa Association of Governments 2011. MAG does not explain its assumption that calculations designed to assess bicycle facilities also apply to pedestrian facilities. On one hand, it seems like common sense to assume that a new trail would also result in a shift from driving to walking, but on the other none of the CMAQ tools that use this approach cite supporting research. Under the MAG approach, a bicycle and pedestrian trail produces twice the reduction in vehicle trips as a bicycle-only facility, because both bicycle and pedestrian mode shifts are assessed using the same calculations and assumptions, but only results in around 25 percent additional VMT reductions, because pedestrian trips are roughly one-quarter the length of bicycle trips.

11 Atlanta Regional Commission 2014.

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