Quantifying Reductions in Vehicle Miles Traveled from New Pedestrian Facilities

Technical Documentation

California Climate Investments Quantification Methods Assessment
California Air Resources Board
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Prepared by:
Jamey Volker with Susan Handy, Alissa Kendall and Elisa Barbour
Institute of Transportation Studies, University of California, Davis

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Section A. Introduction

Under California's Cap-and-Trade program, the State's portion of the proceeds from Cap-and-Trade auctions is deposited in the Greenhouse Gas Reduction Fund (GGRF). The Legislature and Governor enact budget appropriations from the GGRF for State agencies to invest in projects that help achieve the State's climate goals. These investments are collectively called California Climate Investments.

Senate Bill (SB) 862 requires the California Air Resources Board (CARB) to develop guidance on reporting and quantification methods for all State agencies that receive appropriations from the GGRF. Guidance includes developing quantification methodologies for greenhouse gas (GHG) emission reductions and other social, economic, and environmental benefits of projects, referred to as "co-benefits." CARB develops quantification methodologies to provide project-level GHG emission or co-benefit estimates that are supported by empirical literature. This work relies on a review of the available science, coordination with the administering agencies, and outside experts and academic partners to obtain technical assistance and expertise, as needed. The quantification methodologies are developed to:

- Support calculating the estimated GHG emission reductions and applicable co-benefits for individual projects;
- Apply to the project types proposed for funding;
- Provide uniform methodologies that can be applied statewide and are accessible by all applicants;
- Use existing and proven tools or methodologies, where available;
- Include the expected period of time for when GHG emission reductions and co-benefits will be achieved; and
- Identify the appropriate data needed to calculate GHG emission reductions or co-benefits.

CARB may review and update GHG quantification methodologies and co-benefit assessment methodologies periodically based on: new or evolving project types; new legislation; available resources; new scientific developments or tools, or modifications in the analytical tools or approaches upon which the methodologies were based; or input from administering agencies or the public.

This report summarizes research outcomes in an effort to update CARB's current methodology for estimating GHG emission reductions adding new pedestrian facilities, including sidewalks and shared-use Class I bicycle paths. At least three programs offer GGRF funding for projects with new pedestrian facilities. They include the Strategic Growth Council's Affordable Housing and Sustainable Communities (AHSC) Program, the Natural Resources Agency's Urban Greening Grant (Urban Greening) Program and the Department of Transportation's (Caltrans') Active Transportation Program (ATP) (CARB, 2016, 2018, 2019).

To measure GHG emissions reductions from new pedestrian facilities, CARB currently relies on a method (the "CMAQ method") it published with Caltrans in 2005 for calculating GHG emissions reductions from new bicycle facilities (CARB, 2016, 2018, 2019; CARB & Caltrans, 2005). The data on which that method is based are even older, mostly from the 1990s (see section B of this report).

This report reviews the more recent literature to determine whether and how the CMAQ method could be modified to better reflect emerging data and methods. This review summary focuses on the first – and most difficult – step in the GHG emissions reduction quantification method: estimating reductions in vehicle miles traveled (VMT).

CARB currently uses the same equation for estimating VMT reductions from new pedestrian facilities as for estimating reductions from bicycle facilities (see section B). This equation is based (except for the trip length factor) on bicycling research, which is separately reviewed in the companion technical report, "Quantifying Reductions in Vehicle Miles Traveled from New Bike Paths, Lanes, and Cycle Tracks" (Bike Facility Report). The evidence in the literature reviewed for this report is too limited to justify developing a separate estimate on methodology just for pedestrian infrastructure. However, the literature indicates an opportunity to update multiple factors in the current methodology for use with pedestrian facilities, some based on the pedestrian facility literature and some, where the walking literature is lacking, based on the bicycling literature. The literature also indicates that CARB could add another factor – a proximity minimum – based on activity center density.

This report also explores how VMT reductions from new pedestrian facilities could be quantified using the alternative quantification method developed for bicycle projects in the Bike Facility Report, which relies on existing bicycle traffic rather than vehicular traffic (section E).

Section B. Existing Quantification Method

CARB published its current method for quantifying GHG emission reductions from new pedestrian facilities in its most recent GHG emission quantification methodologies for the AHSC, Urban Greening, and ATP programs (CARB, 2016, 2018, 2019). Its method "match[es] the method for calculating GHG emission reduction for bike facilities" (CARB, 2017b [7]).

CARB does not explicitly define "pedestrian facilities" in its published GHG emissions reduction quantification methodologies for the AHSC, URBAN GREENING or ATP programs. But it implies, through examples and by requiring a facility "length" input for VMT reduction quantification, that pedestrian facilities are pedestrian paths, like "shared-use" Class I bike paths, sidewalks or "pedestrian passageway[s] over several lanes of heavy traffic" (CARB, 2017b, [23]).

CARB bases its current GHG emissions reduction quantification method for new pedestrian and bicycle facilities on the premise that emissions are reduced by "replacing auto trips with walking or bicycle trips" (CARB, 2016 [1], 2017b [23]). The two-step method first estimates the annual VMT the new pedestrian facility would reduce. It then estimates the quantity of GHG emissions associated with that avoided VMT, based on auto vehicle emissions factors for the first and last years in the expected useful life of the project. This review focuses on the first step: estimating reduced VMT.

CARB's current method estimates the annual VMT reductions from new pedestrian facilities using Equation 1 (CARB, 2016 [B-1], 2018 [26], 2019 [16]):

Equation 1: Auto VMT Reductions (current method)

$$Auto\ VMT\ Reduced = (D) * (ADT) * (A + C) * (L)$$

Where,

			Units
D	=	days of use per year (default is 200 days)	Days
ADT	=	annual average two-way daily vehicular traffic on parallel road (project-specific data, with a maximum of 30,000)	Trips/day
A	=	adjustment factor (table lookup value)	-
C	=	activity center credit (table lookup value)	-
L	=	walking trip length (1.0 miles/trip in one direction)	Miles/trip

The adjustment factor and activity center credit tables from CARB's 2016 report are replicated below in Tables 1 and 2. The multi-component adjustment factor uses mode share and facility-level bicycle ridership change data[1] and assumptions to estimate how much of the measured ADT would be converted to walking trips after pedestrian facility

[1] As mentioned, the VMT reduction quantification method for new pedestrian facilities is based on the quantification method for new bike facilities and its supporting data.

installation. The activity center credit is an accessibility proxy that increases the adjustment factor for pedestrian facilities that are closer to more "activity centers," like banks, churches, hospitals, light rail stations, office parks, post offices, public libraries, shopping areas, grocery stores, or schools and universities (CARB, 2016 [B-2], 2018 [28], 2019 [17]).

Table 1. Adjustment Factor (A) Lookup Table

Average Daily Traffic (ADT)	Pedestrian Project Length (one-direction)	A (for cities with population >250,000 and non-university towns <250,000)	A (for university towns with population <250,000)
ADT ≤12,000 vehicles per day	≤1 mile	.0019	.0104
	>1 mile & ≤2 miles	.0029	.0155
	>2 miles	.0038	.0207
12,000<ADT ≤24,000 vehicles per day	≤1 mile	.0014	.0073
	>1 mile & ≤2 miles	.0020	.0109
	>2 miles	.0027	.0145
24,000<ADT≤30,000 vehicles per day (max is 30,000)	≤1 mile	.0010	.0052
	>1 mile & ≤2 miles	.0014	.0078
	>2 miles	.0019	.0104

Table 2. Activity Center Credit (C) Lookup Table

Count Your Activity Centers if There Are…	Within ½ Mile of the Project Area	Within ¼ Mile of the project Area
3	.0005	.001
>3 & <7	.0010	.002
≥7	.0015	.003

The adjustment factors in Table 1 "were derived from a limited set of bicycle commute mode split data for cities and university towns in the southern and western United States,"[2] then multiplied by 0.7[3] to "estimate potential auto travel diverted to bikes" (same factor assumed for auto-walking substitution) and again by a 0.65 "growth factor" to "estimate the growth in bicycle trips from construction of the bike facility"[4] (same

[2] As compiled by the Federal Highway Administration in its 1992 National Bicycling and Walking Study.

[3] 0.7 is reported as the 2000-2001 California statewide travel survey estimate of auto mode share of all trips in California.

[4] 0.65 "represents the average growth rate in bike trips from a new bike facility as observed in before and after data for bike projects in U.S. DOT's 'A Compendium of Available Bicycle and

factor used for pedestrian trip growth) (CARB & Caltrans, 2005, 31). However, it is unclear from the method documentation what portion of the cited mode split data was used to calculate the adjustment factors, or how it was used to create different factors by ADT, pedestrian facility length, city population and "university town" status.

It is also unclear how the activity center credits were derived, as there is no documentation for this component of the method.

Without knowing exactly how the adjustment factors and activity center credits were calculated, and because it was not within the scope of work for this report to further unpack their derivation, no specific modifications to the values listed in Tables 1 and 2 are suggested. However, recent research indicates that it might be appropriate to use a cordon based on activity center proximity to limit project VMT reduction estimates for less-accessible locations. The reviewed literature also indicates that at least three of the inputs to the adjustment factors should be updated: auto mode share, walking mode share (or bicycling mode share, if CARB wishes to keep the bike and pedestrian facility quantification methods "matched") and the "growth rate" for walking and/or bicycle trips following new facility construction.

For example, the current method uses an estimate of auto mode share (0.7) that more recent data suggest might be low. The 2010-2012 California Household Travel Survey data show that 76.2% of all trips are made by auto (49.3% as an auto/van/truck driver, and 25.9% as a passenger), while 16.6% are walking trips (Caltrans, 2013, 4). Moreover, auto mode share is a poor and exaggerated proxy for modal substitution[5] in any event, as detailed in the Modal Substitution section.

As detailed in the Facility-level Pedestrian Usage Change section, the assumed 0.65 "growth rate" for cycling trips following new facility construction also appears to be low, at least for Class I bike paths, Class II bike lanes, and Class IV cycle tracks that do not replace existing Class II facilities. Recent research indicates the growth rate might be closer to 1.0 for those facilities. If CARB wishes to keep the bike and pedestrian facility quantification methods "matched," it could update the growth rate figure accordingly for both types of projects. There is currently insufficient evidence from facility-level studies to develop a walking-specific growth rate for new pedestrian facilities.

Pedestrian Trip Generation Data in the United States'" (CARB & Caltrans, 2005, 31). After independently reviewing the DOT Compendium, it could still not be determined how the 0.65 number was calculated. Most of the bicycle count studies summarized in the Compendium did not measure *changes* in ridership following addition of a facility; rather, they primarily reported 1-time counts or multiple counts on existing facilities without any "before" counts (U.S. Department of Transportation, 1994). Indeed, DOT confirms in the Compendium that it "found few sources of before-and-after data" (U.S. Department of Transportation, 1994, 8-1).

[5] As used in this review summary, the "substitution" rate is the percentage of pedestrians (or bicyclists, if CARB wishes to keep the bike and pedestrian facility quantification methods "matched") who would have otherwise, without the bicycle facility in question, made the same trip by auto.

Recent studies also suggest that the pedestrian trip length input to the VMT reduction equation should be updated.

The amount and quality of pedestrian-related research and data collection since Caltrans published the CMAQ method in 2005 has not increased as much as for bicycling-related research. And, in contrast to the alternative quantification method developed in the companion Bike Facility Report, there is insufficient facility-level evidence to develop an alternative quantification method for new pedestrian facilities using solely walking-specific factors. But if CARB wishes to continue matching the bike and pedestrian facility quantification methods, it could use the alternative bike facility quantification method for pedestrian facilities, using walking-specific factors where available, just as it does with the current bike facility quantification method.

Section C. Literature Review Methodology

This report focuses on the first step in CARB's method for quantifying GHG emission reductions from new pedestrian facilities:[6] estimating VMT reductions. Thus, this report does not examine the factors relevant to the second step in CARB's methodology (calculating the GHG emissions from the avoided VMT).

The walking (and, to the extent relevant, bicycling) literature is reviewed to determine whether and how CARB's current VMT reduction estimation method could be modified to better reflect emerging data and methods. This review summary focuses on academic, governmental and professional consultant studies related to those inputs to the current quantification method – or the components of inputs – whose values are clearly derived in the methodology documentation, specifically the facility use factor (section D, Facility-level Pedestrian Usage Change), walking trip length (section D, Walking Trip Length), and the mode share (section B and section D, Modal Substitution section) and facility-level bicycle ridership change (section D, Facility-level Pedestrian Usage Change) values used to calculate the adjustment factors. The report does not probe the activity center credit values because it is unclear how they were derived. However, the reviewed literature does indicate that CARB could add another factor – a proximity minimum – based on activity center density (section D, Activity Center Cordon).

Previous literature reviews on related issues were used to guide the initial literature selection and review, focusing on studies from 2005 (the CMAQ method publication date) onwards (Burbidge, 2016; Ewing & Cervero, 2010; Handy, Sciara, & Boarnet, 2014; Krizek, Forsyth, & Baum, 2009; Mead, Zegeer, & Bushell, 2014; Saelens & Handy, 2008; Talen & Koschinsky, 2014; Turner, Singh, Quinn, & Allatt, 2011). That was augmented by reviewing the relevant studies cited in the first round of articles surveyed, along with additional relevant peer-reviewed journal articles, academic research reports and governmental or professional consultant reports identified through searches on Google, Google Scholar and the Transportation Research International Documentation (TRID) database, using search terms combining "walking," "sidewalk" and "pedestrian" variously with "usage," "substitution," "count," "intervention," "before-and-after," "trip length," and "seasonal." Only English-language literature was reviewed, with a focus on studies from the United States, and particularly California. All the literature that was both reviewed and cited herein is listed in section F.[7]

[6] As discussed above, for purposes of this review report, "pedestrian facilities" are pedestrian paths, like "shared-use" Class I bike paths, sidewalks or "pedestrian passageway[s] over several lanes of heavy traffic" (CARB, 2017b, [23]). They do not include pedestrian path "improvements," such as street crossing treatments (Turner et al., 2011), street furniture additions, tree plantings or sidewalk widening.

[7] A list of the reviewed but uncited literature is available upon request.

Section D. Review of Quantification Method Assumptions and Components

CARB's method for estimating GHG emission reductions from new pedestrian facilities assumes that infrastructure can increase walking levels – particularly walking for commute or other utilitarian purposes (often referred to in the literature, as well as in this report, as "transport" walking) – and reduce VMT. And the literature generally supports those assumptions (Handy, Sciara, et al., 2014; Krizek, Forsyth, et al., 2009; Saelens & Handy, 2008).

Numerous studies have found statistically significant correlations between objective measures of sidewalk presence, extent, or quality and transport walking, using disaggregate cross-sectional data (Ewing, Greenwald, Zhang, & et al., 2009; Fan, 2007; Forsyth, Hearst, Oakes, & Schmitz, 2008; Gunn, Lee, Geelhoed, Shiell, & Giles-Corti, 2014; McCormack et al., 2012; Rodríguez & Joo, 2004). Using the results from three of those studies, Ewing and Cervero (2010) calculated respective elasticities of 0.27, 0.12 and 1.23 (Ewing et al., 2009; Fan, 2007; Rodríguez & Joo, 2004). For every 1-percent increase in sidewalk coverage within respondents' neighborhoods in Portland, Oregon, respondents would increase their walk mode choice by 0.27 percent; for every 1-percent increase in sidewalk length within respondents' block groups in Orange, Durham and Wake counties in North Carolina, they would increase their daily walking time by 0.12 percent; and, for every 1-percent increase in proportion of respondents' shortest route to campus with a sidewalk in Chapel Hill, North Carolina, respondents would increase their walk mode choice by 1.23 percent (Ewing & Cervero, 2010; Handy, Sciara, et al., 2014). However, as Handy, Sciara and Boarnet (2014, 3) note, because the Rodriguez and Joo (2004) "study focuses on university students and employees in a small city," the 1.23-elasticity result is "not likely to be relevant to most communities."

In addition to objective measures of pedestrian facilities, at least one disaggregate cross-sectional study found a positive correlation between perceived pedestrian infrastructure (including sidewalks) and the number of minutes walked per week for commute or other utilitarian purposes (Kerr et al., 2016).

A number of disaggregate cross-sectional studies have also found positive statistical correlations between sidewalk presence or extent and automobile usage (Fan, 2007; Frank et al., 2011; Guo & Gandavarapu, 2010; Kitamura et al., 1997). However, as discussed in Handy et al. (2014), the effect is smaller than for transport walking. For example, using household travel survey and county sidewalk layer data from King County, Washington, Frank et al. (2011) found that for every 1-percent increase in the ratio of sidewalks to streets within 1 kilometer of respondents' homes, household VMT decreased by 0.05 percent. For the North Carolina respondents in Fan (2007), Ewing and Cervero (2010) calculated that a 1-percent increase in sidewalk length for the block group reduced VMT by 0.02 percent. And for the respondents in the San Francisco Bay Area in Kitamura et al. (1997), Ewing and Cervero (2010) calculated that the presence (versus not) of sidewalks in the neighborhood reduced the number of vehicle trips by 0.14 percent.

Another study used longitudinal data on the travel behavior and other characteristics of people living within 5 kilometers of three separate pedestrian (and bicycle) facility additions[8] in England to test, via a binary logit model, the effect on mode shift (between auto and active travel) of exposure to the facility (Song et al., 2017). They found that use of the facilities was statistically significantly associated with modal shift from auto use to walking and bicycling, but that distance (from residence) to the facilities was not.

However, while the aforementioned studies support the primary assumption underlying CARB's current quantification methodology – that pedestrian facilities increase transport walking and reduce VMT – they are not readily usable to calculate, at the facility level, VMT reductions associated with new pedestrian facilities. For example, most studies do not attempt to measure the impact on walking – let alone VMT – of a particular facility. In addition, all of them focus on the impact of pedestrian facilities on residents of the relevant neighborhood, excluding the impact on non-resident users of the facilities. They also all rely on surveys and statistical modeling, which can make comparison of results and effect magnitudes difficult, among other issues.[9]

More useful for updating the factors in CARB's quantification method are studies reporting pedestrian counts (or, as relevant, bicyclist counts) before and after a pedestrian facility installation (which can be used to calculate the usage "growth rate"), or presenting information relevant to contextualizaing those counts, specifically modal substitution, trip length, and seasonal adjustment estimates. As discussed above, all four are factors in CARB's current VMT reduction equation. And all four are also essential to the potential alternative VMT reduction equation developed in the Bike Facility Report, and discussed in the pedestrian facility context at the end of this report.

As many authors have reported, however, there is a shortage of published research in the United States – as well as internationally – on the before-and-after impacts on pedestrian usage of adding pedestrian facilities (Cottrell & Pal, 2003; Frank et al., 2011; Handy, et al., 2014; Mead et al., 2014; Turner et al., 2011). The few relevant studies we found are discussed in section D. But because the evidence in that literature is too limited to warrant modifying the growth rate and auto substitution rate factors CARB currently uses in estimating VMT reductions from new pedestrian facilities – and

[8] Two traffic-free pedestrian/bike bridges, and conversion of an "informal" riverside footpath into a boardwalk.

[9] The difficulties associated with using studies that employ statistical modeling to identify and determine the strength of walking predictors, as most studies do, or to detect differences in walking levels or propensities, are discussed in the similar bicycling context in the Bike Facility Report (see, for example, Table 5). For example, it is often impossible to directly compare the magnitude of the model outputs between studies because of the different methodologies used, which can lead to very different results (Krizek, Handy, & Forsyth, 2009, 725, 736; Götschi, Krizek, McGinnis, Lucke, & Barbeau, 2011, 14; Handy, Tal, & Boarnet, 2014).

because the current methodology already uses values for those factors based on data from bicycle, not pedestrian, facilities – the relevant discussions in the Facility-level Pedestrian Usage Change and Modal Substitution subsections of Section D are augmented with summaries of the relevant findings from the companion Bike Facility Report. Where CARB cannot update the pedestrian facility quantification factor values based on pedestrian facility studies, it should at least update those values in step with any updates to the bike facility quantification method.

Facility-level Pedestrian Usage Change

Pedestrian counts provide an essential empirical measure of walking trips along a given route, and the change in usage of that route after installation of a new pedestrian facility (Götschi et al., 2011; Matute et al., 2016 [same for bicycling counts]). Indeed, CARB's current method for estimating VMT reductions from new pedestrian facilities uses a before-and-after estimate of usage "growth rate" (0.65).

However, the 0.65 growth rate was estimated for *bicycle* facilities. And the bicycle count data available when CARB and Caltrans published the CMAQ method was limited (U.S. Department of Transportation, 1994; see footnote 4 above). It thus bears assessing both the literature for (1) before-and-after *pedestrian* counts and, barring sufficient evidence to develop a walking-specific growth rate, (2) more recent (than 1994) before-and-after bicycle counts.

The before-and-after pedestrian counts from studies reviewed for this report are presented in Table 3. As shown, the counts are insufficient to support developing a walking-specific growth rate. The counts from Fitzhugh et al. (2010) do not distinguish between bicyclists and pedestrians. And the counts from Boarnet et al. (2005) are specific to children walking to and from school, and might not be representative of other situations.

However, even without enough evidence to develop a walking-specific growth rate, CARB could at least update the 0.65 growth rate it uses for quantifying VMT reductions from both new bicycle and pedestrian facilities. As discussed in the companion Bike Facility Report, that growth rate is based on older – and unclear – data. The more recent data reviewed in the Bike Facility Report (section F, Facility-Level Bicycle Ridership Change) indicate that the growth rate might be closer to 1.0, at least for Class I (which are often shared-use paths also allowing pedestrian use), Class II and Class IV bike facilities.

Table 3. Before/After Pedestrian Counts on New Pedestrian Facilities

Study	Location	Facility Description	Facility Length	Before/After Pedestrian Counts (Period)	Percent Change	Notes
Fitzhugh, Bassett, & Evans (2010)	Knoxville, TN	Urban greenway in a neighborhood that previously lacked connectivity of the residential pedestrian infrastructure to non-residential destinations was retrofitted with an eight-foot-wide pedestrian and bike path, which connected to nearby retail establishments and schools	2.9 miles	Median = 4.5/13 (median of peak two-hour morning, midday and afternoon counts)	Median = 189%	Counts did not distinguish between bicyclists and pedestrians. Before and after counts taken in the affected neighborhood at a "location that provided distinct views of physical activity," during two-hour periods in the morning, midday and afternoon over two days in March 2005 (pre-intervention) and March 2007 (post-intervention)
Boarnet, Day, Anderson, McMillan, & Alfonzo (2005)	Malibu, CA	Safe Routes to Schools program-funded installation of a pedestrian pathway of decomposed granite in a predominately residential area with a "rural character"	Not reported	Total = 138/152 (2-day counts of pedestrian trips to and from school on installed facility)	10%	Counts collected during 2-day periods both before and after facility construction (length of time between data collection and facility construction not reported). Counts collected from 30 minutes before to 15 minutes after the start of the school day, and from 15

	Murrieta CA	Safe Routes to Schools program-funded installation of a sidewalk, curb and gutter in a neighborhood with a mix of residential, commercial and civic land uses	Not reported	Total = 64/89 (2-day counts of pedestrian trips to and from school on installed facility)	39%	minutes before to 30 minutes after the end of the school day.
	El Sobrante, CA	Safe Routes to Schools program-funded installation of a sidewalk gap closure in a suburban neighborhood	Not reported	Total = 691/1,146 (2-day counts of pedestrian trips to and from school on installed facility)	66%	
	Yucaipa, CA	Safe Routes to Schools program-funded installation of a sidewalk gap closure in a neighborhood changing from a rural to suburban character	Not reported	Total = 274/302 (2-day counts of pedestrian trips to and from school on installed facility)	10%	
	San Bernardino County, CA	Safe Routes to Schools program-funded installation of a sidewalk gap closure	Not reported	Total = 2/19 (2-day counts of pedestrian trips to and from school on installed facility)	850%	

Seasonal Effects

An estimate of annual pedestrian usage change is essential for estimating annual VMT reductions from a new pedestrian facility. However, it can be difficult to translate hourly or daily counts into annual volumes. Pedestrian volumes vary substantially by hour, day and season (Johnstone et al., 2017; Jones et al., 2010; Ryus et al., 2014; Schneider et al., 2009). CARB's current quantification method attempts to account for the seasonal (mostly weather-related) variation by assuming the new pedestrian facility would only be used 200 days out of the year. But more sensitive adjustment factors are now available, and will become increasingly accurate with the more widespread use of continuous automatic counters for active transportation.[10]

No comprehensive survey of local and regional governments was done to determine which California jurisdictions have continuous active transportation count data with which locally specific adjustment factors could be (or have been) calculated, but at least some do. For example, San Francisco and San Diego both have dozens of continuous pedestrian and/or bike counters.[11] A year's – or even a month's – worth of continuous pedestrian count data from even a single counter can be enough to calculate seasonal adjustment factors (Ryus, Ferguson, & Lautsen, 2014).

Schneider et al. (2009) detail how to use continuous automatic count data from 11 counters in Alameda County, California to calculate daily/hourly adjustment factors to apply to short-duration (2-hour) manual pedestrian counts to estimate weekly – and even annual – average daily pedestrian usage. Using 11 automated counters in different settings throughout the county also allowed them to account for location type in calculating their adjustment factors. While the authors caution that their study was "exploratory," and that "additional research is needed to identify the accuracy of these factors in different communities and under different conditions," their method is illustrative of how seasonal – and location type – adjustment factors can be developed and applied using local continuous bike counts. In areas without sufficient local continuous bike counts, planners can use a generic set of seasonal adjustment factors developed from project-level data across the United States.

Based on continuous counts from across the nation, the National Bicycle and Pedestrian Documentation Project developed a set of "count adjustment factors" to

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[10] Automated pedestrian and bike counters use a range of technologies – passive infrared, active infrared, radio beams, pressure pads, etc. – to digitally record bike trips along a corridor without on-site human counting or monitoring (Ryus, Ferguson, Lausten, et al., 2014; San Francisco Municipal Transportation Agency, 2016). Jurisdictions are increasingly embedding these devices more permanently into their street and path infrastructure to obtain continuous counts over longer periods of time than an average manual count.

[11] See, for example, https://www.sandag.org/index.asp?classid=34&projectid=496&fuseaction=projects.detail, and http://archives.sfmta.com/cms/rpedmast/documents/FinalPedestrianCountReport6_17_11.pdf

convert hourly bicyclist and pedestrian counts to annual (and average annual daily) volumes (National Bicycle and Pedestrian Documentation Project, 2009). The authors caution that "more year-long automatic count data is needed from different parts of the country" for pedestrian and on-street bicyclist counts outside of "multi-use paths" and "pedestrian and entertainment areas" (like most downtowns) (National Bicycle and Pedestrian Documentation Project, 2009, 1). But they conclude that "enough data now exists to allow us to adjust counts done [during] almost any period on multi-use paths and pedestrian districts to an annual figure" (National Bicycle and Pedestrian Documentation Project, 2009, 1). And it is facilities with access to desirable non-residential destinations, like downtown pedestrian districts, that are most likely to increase transport walking (Handy et al., 2014; Hoehner et al., 2005; Krizek et al., 2009).

The National Bicycle and Pedestrian Documentation Project seasonal adjustment steps are summarized as follows, with reference to Tables 4, 5 and 6 below:

- Start with an hourly pedestrian count. To improve count estimation accuracy, the National Bicycle and Pedestrian Documentation Project "strongly encourage[s] that all estimates be based on the average of at least two… and preferably three… counts during the same time period and week" (National Bicycle and Pedestrian Documentation Project, 2009, 1).
- Multiply the hourly count by 1.05 (to reflect pedestrians who travel between 11 p.m. and 6 a.m.).
- Identify the weekday hour (and season and area/facility type) of your count, then divide your hourly count by the appropriate factor listed in Table 4 below (Table 1 of the National Bicycle and Pedestrian Documentation Project's report) to get a daily user estimate.
- Divide the daily user estimate by the weekly adjustment factor in Table 5 below (Table 2 of the report) for the day of the week on which your counts were taken to obtain a weekly user estimate (holidays use weekend rates).
- Multiply the weekly user estimate by 4.33 to obtain a monthly user estimate for the month in which the counts were taken.
- Divide the monthly user estimate by the appropriate monthly adjustment factor from Table 6 below (table 3 of the report) to get the annual user estimate.
- Divide by 365 to produce an average annual daily pedestrian trip (AADPT) estimate.

Equation 2 represents these steps in mathematical form.

Equation 2:

$$AADPT = \frac{(hourly\ count) * 1.05 * 4.33}{(hourly\ adjustment\ factor) * (daily\ adjustment\ factor) * (monthly\ adjustment\ factor) * 365}$$

Table 4. Hourly Adjustment Factors

	April-September					**October-March**			
	Multi-Use Path		Pedestrian & Entertainment Area			Multi-Use Path		Pedestrian & Entertainment Area	
	Mon-Fri	Sat-Sun	Mon-Fri	Sat-Sun		Mon-Fri	Sat-Sun	Mon-Fri	Sat-Sun
0600	2%	1%	1%	1%	0600	2%	0%	0%	0%
0700	4%	3%	2%	1%	0700	4%	2%	1%	1%
0800	7%	6%	4%	3%	0800	6%	6%	2%	2%
0900	9%	9%	5%	3%	0900	7%	10%	4%	4%
1000	9%	9%	6%	5%	1000	9%	10%	5%	5%
1100	9%	11%	7%	6%	1100	9%	11%	8%	8%
1200	8%	10%	9%	7%	1200	9%	11%	10%	10%
1300	7%	9%	9%	7%	1300	9%	10%	13%	13%
1400	7%	8%	8%	9%	1400	9%	10%	11%	11%
1500	7%	8%	8%	9%	1500	8%	10%	8%	8%
1600	7%	7%	7%	9%	1600	8%	8%	7%	7%
1700	7%	6%	7%	8%	1700	7%	5%	6%	6%
1800	7%	5%	7%	8%	1800	6%	3%	6%	6%
1900	5%	4%	7%	8%	1900	4%	2%	6%	6%
2000	4%	3%	7%	8%	2000	2%	1%	6%	6%
2100	2%	2%	6%	8%	2100	2%	1%	5%	5%

Source: National Bicycle and Pedestrian Documentation Project (2009, table 1)

Table 5. Daily Adjustment Factors

Day	Factor
Monday	14%
Tuesday	13%
Wednesday	12%
Thursday	12%
Friday	14%
Saturday	18%
Sunday	18%

Source: National Bicycle and Pedestrian Documentation Project (2009, table 2)

Table 6. Monthly Adjustment Factors by Climate Area

Month	Long Winter & Short Summer	Moderate Climate	Very Hot Summer & Mild Winter
January	3%	7%	10%
February	3%	7%	12%
March	7%	8%	10%
April	11%	8%	9%
May	11%	8%	8%
June	12%	8%	8%
July	13%	12%	7%
August	14%	16%	7%
September	11%	8%	6%
October	6%	6%	7%
November	6%	6%	8%
December	3%	6%	8%

Source: National Bicycle and Pedestrian Documentation Project (2009, table 3)

In the absence of locally specific continuous count data, or until California-wide seasonal adjustment factors are developed, AHSC, Urban Greening and ATP applicants could follow the steps and factors provided by the National Bicycle and Pedestrian Documentation Project to extrapolate AADPT from hourly pedestrian count data, at least for projects near multi-use paths or denser pedestrian and entertainment areas.

However, calculating AADPT would only be useful if CARB – and the AHSC, Urban Greening and ATP-administering agencies – switch from the current quantification method for new pedestrian facilities to the alternative quantification method developed for new bike projects in the companion Bike Facility Report, and applied to new pedestrian facilities in section E of this report.

Walking Trip Length

CARB's current quantification method uses a default one-way walking trip length of 1.0 miles. It is unclear what that value is based on. But the most recent California- and nation-wide data reviewed for this report indicate that 1.0 miles might be longer than the average walking trip length.

The 2009 National Household Transportation Survey (NHTS),[12] for example, shows a 0.7-mile average one-way walking trip length across all trip purposes (Kuzmyak & Dill, 2012). And the 2010-2012 California Household Travel Survey shows an even shorter, 0.3-mile average walking trip length across all trip purposes (Caltrans, 2013, 119). Because this is the most recent California-wide estimate, CARB might want to use this 0.3-mile average as the default walking trip length going forward in its quantification methodology.

More locally specific trip length estimates lack standardization and might therefore not be ideal for use in a statewide VMT reduction quantification method.

Modal Substitution

Estimating VMT reductions from new pedestrian facilities requires assumptions not only about changes in facility usage and average trip lengths, but also about modal substitution – the percentage of the new pedestrian trips that would have otherwise (without the new facility) been made by automobile. The current quantification method uses a 0.7 substitution rate, which is based on an old California auto mode share figure for all (transport and recreational) trips and assumes that modal substitution rates are equivalent to existing mode shares.

More recent stated substitution data from intercept surveys of pedestrians conducted by Thakuriah et al. (2012) in Chicago indicate that the actual substitution rate is much lower, as summarized in Table 7. The auto substitution percentages for the five new sidewalks studied ranged from 6.25 to 38.1 percent, with an approximate average of 21.5 percent. However, it is unclear if Thakuriah et al.'s respondent pool included any people who walked the same route before facility installation anyway. If it did, the true auto substitution rate (using as the denominator just those pedestrians who started using the route *after* facility installation) would be higher.

Piatkowski et al. (2015) report much higher auto substitution percentages, ranging from 23.7% to 72.4%. But they are not directly comparable to the other substitution percentages from Thakuriah et al. (2012) for at least two reasons. First, Piatkowski et al. (2015) did not survey pedestrians on *new* facilities, and thus did not measure route shift. Second, their survey results combine cyclists and pedestrians.

The reviewed evidence on the auto substitution rate of *pedestrians* on new facilities is thus limited. However, as discussed in the companion Bike Facility Report, there is much more evidence – including from California – on the auto substitution rate of

[12] The NPTS was renamed the NHTS beginning with the 2001 NHTS. The most recent NHTS was completed in 2017, but relevant summaries of the data were not yet publicly available at the time this report was written, nor were they prepared separately for this report.

bicyclists on new bicycle facilities. The available data there indicate an overall stated substitution rate between 0.2 and 0.3 (for cyclists who did not bike on the same route prior to bicycle facility installation), with an auto substitution rate of about 0.1.

Thus, even without enough evidence to develop a pedestrian-specific auto substitution rate, CARB could at least update the 0.7 substitution rate it currently uses for quantifying VMT reductions from both new bicycle and pedestrian facilities. The 0.1 substitution rate might be conservative for pedestrians, given the data from Thakuriah et al. (2012), but it is much closer to the 0.215 rate reported in that study than the 0.7 rate used in the current quantification method.

Table 7. Modal Substitution Estimates

Study	Location	Facility Description	Survey Method	Auto-to-Walk Substitution %	Other-to-Walk Substitution %	Route Shift %	New Trip %
Piatkowski et al. (2015)	Denver, CO	Multiple intercept survey locations. See source paper for details.	Intercept survey (utilitarian cyclists and pedestrians only; results combined for cyclists and pedestrians; n= 56)	23.7 %	32.2% (bus or light rail) 20.5% (walked or biked, whichever not currently doing) 5% (other)	Not measured	18.6%
	Boulder, CO	Multiple intercept survey locations. See source paper for details.	Intercept survey (utilitarian cyclists and pedestrians only; results combined for cyclists and pedestrians; n= 59)	57.1%	30.3% (bus or light rail) 9% (walked or biked, whichever not currently doing) 0% (other)	Not measured	3.6%

	Littleton, CO	Multiple intercept survey locations. See source paper for details.	Intercept survey (utilitarian cyclists and pedestrians only; results combined for cyclists and pedestrians; n= 29)	72.4%	17.3% (bus or light rail) 0% (walked or biked, whichever not currently doing) 3.5% (other)	Not measured	0%
	Sacramento, CA	Multiple intercept survey locations. See source paper for details.	Intercept survey (utilitarian cyclists and pedestrians only; results combined for cyclists and pedestrians; n= 11)	27.3%	45.4% (bus or light rail) 9.1% (walked or biked, whichever not currently doing) 9.1% (other)	Not measured	0%
	Davis, CA	Multiple intercept survey locations. See source paper for details.	Intercept survey (utilitarian cyclists and pedestrians only; results combined for cyclists and pedestrians; n= 37)	25.0%	8.3% (bus or light rail) 47.2% (walked or biked, whichever not currently doing) 8.3% (other)	Not measured	11.2%

Thakuriah et al. (2012)	Chicago, IL (Bedford Park)	2,550-foot-long sidewalk near transit in an industrial/commercial area	Intercept survey (42 respondents)	11.9% (unclear if denominator includes those who walked via same route previously)	Not reported	Not reported	Not reported
	Chicago, IL (Palatine)	Sidewalk providing access to a commuter train station	Intercept survey (42 respondents)	38.1% (unclear if denominator includes those who walked via same route previously)	Not reported	Not reported	Not reported
	Chicago, IL (Northfield)	Links a high school to the downtown area	Intercept survey (34 respondents)	20.59% (unclear if denominator includes those who walked via same route previously)	Not reported	Not reported	Not reported
	Chicago, IL (Country Club Hills)	~1/2-mile-long sidewalk providing access to the high school	Intercept survey (23 respondents)	30.43% (unclear if denominator includes those who walked via same route previously)	Not reported	Not reported	Not reported

	Chicago, IL (Glenview)	~1-mile-long sidewalk in a residential area providing access to a community park	Intercept survey (16 respondents)	6.25% (unclear if denominator includes those who walked via same route previously)	Not reported	Not reported	Not reported

Activity Center Cordon

CARB's current method for quantifying VMT reductions from pedestrian projects includes an adjustment factor based on proximity to "activity centers," i.e. common non-residential destinations like banks, churches, hospitals, light rail stations, office parks, post offices, public libraries, shopping areas, grocery stores, or schools and universities (CARB, 2016 [B-2], 2018 [28], 2019 [17]). That assumes, in line with the literature, that facilities with access to desirable non-residential destinations are most likely to increase transport walking (Fitzhugh et al., 2010; Handy et al., 2014; Hoehner et al., 2005; Krizek et al., 2009).

CARB could consider going further. Because the literature indicates that facilities with access to non-residential destinations are most likely to increase transport walking, and because walking is the most distance-restricted travel mode (because of its slow speed), CARB could limit funding applicants to claiming GHG reductions only from pedestrian facilities that have at least one activity center (as defined in the current quantification methodology) within a radius of the average walking trip length used in the quantification methodology (currently 1 mile). To avoid being overly conservative and to capture the pedestrian shed of all but the longest-distance pedestrians, CARB could set the cordon radius at some distance greater than the average walking trip length, like the 95th percentile walking trip length.

Section E. Alternative Quantification Method

Given the amount and quality of bicycling-related research and data collection since Caltrans published the CMAQ method in 2005, it is now possible to develop a method for calculating VMT reductions from new bicycle facilities that relies solely on bicycling count data, without using vehicular ADT. Such an alternative method was developed and explained in the companion Bike Facility Report.

The reviewed literature provides insufficient data to develop generalizable *pedestrian*-specific values for all the inputs for the alternative quantification method. But the *approach* – using active transportation counts instead of vehicular ADT to quantify VMT reductions – is just as well suited to pedestrian facilities as it is to bicycle facilities. One reason to rely on pedestrian – just like bicycling – count data rather than vehicular ADT used in the current methodology is that using vehicular ADT assumes that higher auto volumes correlate to higher pedestrian volumes, which is often not the case.

For example, a high-volume arterial running from suburban residential developments in a hilly area to a freeway accessing the metropolitan job center 10 miles away could easily have high vehicular volume but low to no volume of pedestrians walking for transport, due to the topography and distance to non-residential developments. On the other hand, a high-volume arterial in a flat area with high accessibility to residential, commercial and retail uses could have substantial pedestrian traffic, just as the stretch of Telegraph Avenue in the Uptown neighborhood of Oakland, California did even before the city improved pedestrian street crossings, installed Class IV cycle tracks on both sides of the street, and completed other streetscape improvements (McClain & Peterson, 2016).

Just as with bicycling counts, pedestrian counts inherently account for factors like topography and distance that will limit transport walking with or without pedestrian facilities. By contrast, using vehicular ADT requires applying adjustment factors like the proximity to “activity centers” proxy used in CARB’s current method.

Equation 3, as discussed in more detail in the companion Bike Facility Report and modified below for use with pedestrian facilities, is one potential method to estimate VMT reductions from new pedestrian facilities without using vehicular ADT. And while there is insufficient data in the reviewed literature to develop generalizable *pedestrian*-specific values for all the inputs for the alternative quantification method, values from the bicycling literature could be used as defaults to fill those gaps, just as CARB’s current quantification methodology for pedestrian facilities parrots the quantification methodology for bike facilities (with the exception of the trip length factor).

Equation 3: Auto VMT Reductions (alternative method)

$$Auto\ VMT\ Reduced = (D) * (PC) * (S) * (GF) * (AS) * (C) * (T) * (L)$$

Where,

			Units
D	=	days of use per year (default is 365 days, since counts can be adjusted seasonally)	Days/year
PC	=	average hourly (or daily) pedestrian count (either one- or two-direction, depending on whether facility will be one- or two-way; counts taken on the street to be improved with the pedestrian facility, or, in the case of a facility not on an existing street, a parallel street)	Trips/day
S	=	seasonal adjustment factor (adjusts pedestrian count to annual average daily pedestrian trips)	-
GF	=	growth factor (expected rate of increase in pedestrian count, e.g. 1.0 for a 100% increase in trips on the route)	-
AS	=	automobile substitution rate (expected rate at which pedestrians who did not walk on the same route prior to pedestrian facility installation switched from driving, or being driven in, an automobile to walking)	-
C	=	carpool factor (default is 1/1.15, to reflect the California average number of vehicle trips per person trips by personal auto)	-
T	=	trip type factor (optional inclusion for conservative estimates; default is 0.646)	-
L	=	walking trip length (default is 0.3 miles/trip in one direction)	Miles/trip

Values for the first two variables, *D* and *PC*, would be provided by the funding applicant. *D* would have a default of 365, but it could be changed based on local conditions and the type of seasonal adjustment factor used. Where possible, pedestrian counts should be taken in similar fashion across sites, for example by following the National Bicycle and Pedestrian Documentation Project methodology, referenced above in the Seasonal Effects section. The National Bicycle and Pedestrian Documentation Project recommends conducting screen line counts – rather than intersection counts – to identify trends in pedestrian volumes. It provides further guidance on conducting the counts in its “Instructions” manual (National Bicycle and Pedestrian Documentation Project, 2010) and on its website.[13] The website also has standard screen line and other data collection forms for download.

The seasonal adjustment factor, *S*, could use local data where available. But to ensure continuity in application across California, the National Bicycle and Pedestrian Documentation Project’s adjustment factors can be used in the interim, as discussed above in the Seasonal Effects section.

The growth factor, *GF*, could be approximated based on the findings from the count-based studies discussed in the Facility-level Pedestrian Usage Change section of the

[13] http://bikepeddocumentation.org/index.php/downloads

Bike Facility Report, given the dearth of before-and-after pedestrian counts reported in the literature for new pedestrian facilities. It appears from the bicycling literature that a uniform growth rate around 1.0 could be appropriate.

The auto substitution factor, *AS*, could likewise be based on the available data for bicycle projects discussed in the Modal Substitution sections of this report and the companion Bike Facility Report, given the dearth of pedestrian-specific modal substitution rates reported in the reviewed literature. The bicycle facility literature indicates an auto substitution rate of about 0.1. However, the auto substitution factor should be adjusted to account for carpooling (not all pedestrians who would have made the same trip by car would have done it alone).

The carpool factor, *C*, corrects for that, by dividing the total number of substituted trips by the average vehicle occupancy rate (average number of people per auto) used by Caltrans (1.15) (Caltrans, 2016).

The (optional) trip type factor, *T*, is included to correct for the fact that walking trips that are purely for exercise, sport, or recreation are not as likely to substitute for auto trips as utilitarian bike trips are. The default value for *T* is based on the combined share (37.3%) of pedestrian trips made for "vacation" (1.9%) or "other social or recreational" (35.4%) purposes, taken from the 2009 NHTS. The default value is the percentage of all other (non-vacation, social or recreational) trips, calculated as 1-0.354 (=0.646). This approximation of commute and utilitarian trip share is likely conservative, however, because some of the trip purposes categorized as "other social or recreational" are arguably more similar to utilitarian trips than purely recreational trips. Furthermore, the auto substitution factor (from the bicycling literature) already corrects for recreational ridership, as it is based on the substitution rates of all surveyed cyclists combined, regardless of trip purpose (Matute et al., 2016; Monsere et al., 2014; Thakuriah et al., 2012). If the substitution factor, *AS*, were calculated based on only utilitarian trips, it would be quite a bit higher. Including the optional trip type factor thus produces a conservative estimate of VMT reductions from pedestrian facility installation.

The trip length factor, *L*, is based on the average length of walking trips. Currently, CARB uses a 1.0-mile default. But the 2009 NHTS data show a shorter average walking trip length of 0.7 miles, as discussed in the Walking Trip Length section. And the most recent California Household Travel Survey data show a 0.3-mile average walking trip length. Because this is the most recent California-wide walk trip length estimate, it might be the safest – and certainly most conservative – default value to use in this alternative quantification method. In any event, using the average walking trip length would produce a conservative estimate of vehicle miles if the new walking trips are shorter than the driving trips they replace, as would be the case if the pedestrian chooses a closer destination for that trip given the slower speed of walking.

As pedestrian research progresses, the above factors should be re-examined and updated, replaced, or added to as needed. For example, the ridership growth rate and substitution rate factors should be recalculated based on count data from *pedestrian* facilities as more facility-level before-and-after studies are done.

Ease of Applying the Alternative Quantification Method

To gauge how easy it would be to use the alternative quantification method, jurisdictions' housing projects that received funding from AHSC or ATP were surveyed about the type, timing and location of their active transportation (bicycle and pedestrian) and vehicular counts, and who conducted the counts.[14] The active transportation and vehicular count information available online for the jurisdictions was also reviewed. The results, along with the insights from the case study presented in the companion Bike Facility Report, indicate that the alternative quantification method would be at least as easy to use as the existing method, for at least two reasons.

First, once a GGRF funding applicant has the requisite hourly (or daily) pedestrian count data or vehicular ADT, the alternative quantification method can be applied more quickly than the existing method. Default values are available for all other factors in the alternative method besides the pedestrian count, including the seasonable adjustment factor (following the steps and factors provided by the National Bicycle and Pedestrian Documentation Project in the absence of a more locally specific seasonal adjustment factors). The existing method, on the other hand, requires the potentially time-consuming identification and documentation of all the "activity centers" within ½-mile and ¼-mile buffers of the planned pedestrian facility. The activity center proximity analysis was undertaken for the bike facility case study and is described in the Bike Facility Report.

Second, in many jurisdictions it may be just as easy for a funding applicant to obtain the requisite hourly pedestrian count data as the necessary vehicular ADT. Most of the jurisdictions for which information was obtained about their active transportation and auto traffic data collect counts at dozens of locations (including San Francisco, Oakland, Los Angeles, Long Beach, and San Diego), most updated at least annually. And those jurisdictions collectively house more than a third of the AHSC- and ATP-funded projects.

San Francisco, Los Angeles, Long Beach, and San Diego also collect at least some pedestrian count data using continuous counters. As the Alameda County Transportation Commission explains for why it pairs its manual count program with an automated count program, continuous data can "provide valuable insights into variation in the levels of bicycling and walking by time of day, day of week, season and over time," enabling development of local seasonal adjustment factors (Alameda County Transportation Commission, 2012).

[14] Jurisdictions that responded to requests for information on their active transportation and automobile traffic counts include San Francisco, Oakland, Hayward, West Sacramento, Long Beach and San Diego.

As a result of the increased – and increasing – focus on pedestrian and multi-modal planning over the last few years, many of the surveyed jurisdictions have bike count data for nearly as many locations as automobile counts. Indeed, in both San Diego and Oakland, traffic counts are typically multi-modal, collecting pedestrian, bike, and automobile counts simultaneously.

For projects proposed in areas without pedestrian or auto counts, the project applicant would likely have to pay for them regardless of whether the GGRF funding application requires vehicle or pedestrian ADT to estimate VMT reductions. Cash-strapped local governments usually do not fund studies required for development projects by local ordinances and state environmental review laws (Fulton & Shigley, 2012; Rothman, 2011; Thomas, 1993). Some jurisdictions, like Long Beach, actually obtain most of their automobile counts from project applicant-funded consultants through the development and environmental review process.

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