TOWARD AN ACTIVE CALIFORNIA
STATE BICYCLE + PEDESTRIAN PLAN

Evaluation of Programs and Infrastructure

California Department of Transportation

April 2017

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Caltrans CALIFORNIA DEPARTMENT OF TRANSPORTATION

Document Information		
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	Project Title	California State Bicycle and Pedestrian Plan
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Document Revision Schedule			
Review of Existing Documents			
Rev.	Description	Date	Reviewed by
v1	Draft report	3/17/2017	Hugh Louch
v2	Final	4/17/2017	Hugh Louch

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1. Introduction

This report evaluates the potential impacts of statewide investments in walking and bicycling. The focus is on estimating implementation costs for programs and infrastructure across the state. Specifically, three questions are explored:

- What are the benefits and costs of non-infrastructure projects for walking and bicycling such as Safe Routes to School (SRTS) programs?
- How much would it cost to construct the bicycle facilities needed to support a tripling in the statewide bicycle mode share?
- How much would it cost to retrofit the statewide pedestrian network to be accessible?

These questions are answered using a combination of methods including review of the literature for documented effects of programs and infrastructure and cost estimation based on rough unit costs for programs and infrastructure. Developing SRTS programs statewide is estimated at $20M-$300M. The bicycle network required for a tripling of the mode share statewide is estimated at a median cost of $4.32B with a lower bound of $1.28B and an upper bound of $10.2B. Finally, retrofitting the statewide pedestrian network to be accessible is estimated at a midpoint cost of $61B with a lower bound of $25B and an upper bound of $285B.

2. Programs Evaluation

While there is a growing body of literature on the impacts of bicycle and pedestrian infrastructure projects on health, safety, mobility, and air quality, there is little consensus about the impacts of non-infrastructure projects, such as Safe Routes to School programs. In large part, this is the result of a lack of rigorous program evaluations. Through a brief review of existing literature on bicycle and pedestrian program evaluations, including the benefits and costs of these programs, gaps in research are more readily identified.

Literature Review

Most literature on active transportation programming in the United States provides practitioners and advocates descriptive information about programs following the Safe Routes to School model. A small subset of the literature includes research evaluating the effectiveness of program implementation, primarily focusing on changes in safety or travel behavior near school sites. Below is a brief review of some of the most comprehensive active transportation program evaluations.

Marin County, California Safe Routes to School Program Evaluation

Begun in 2000, Marin County's Safe Routes to School program was one of the first of its kind in the country and now includes 58 participating schools. To monitor progress, the Transportation Authority of Marin (TAM) conducts program evaluations, with the most recent evaluations conducted in 2011 and 2016. The 2011 program evaluation documented changes in travel behavior through student hand tallies and changes in perceptions through parent surveys. The collected student hand tally data showed a 38 percent increase in the number of students walking to school from fall 2008 to spring 2011 (16 percent to 22 percent). No change in the number of students bicycling to school was observed in the hand tally data, but the program did observe a 6 percent decrease in drive alone trips from fall 2008 to spring 2011 (51 percent to 48 percent).[1] Questions from the parent survey included distance from home to school, individual travel patterns, program participation, perceptions of the effectiveness of individual program elements, and barriers to allow children to walk and bicycle to school. The 2011 program evaluation also included a comprehensive list of the number and type of program elements completed at individual schools in the 2010-2011 school year[2]

The program's most recent evaluation showed data through the 2014-2015 school year, using the same methods of hand tallies and parent surveys used in the 2011 program evaluation. The collected student hand tally data showed a 4 percent decrease in the number of students walking and bicycling to school from the 2011-2012 school year to the 2014-2015 school year (27 percent to 26 percent), and an 8 percent decrease in the number of students carpooling and riding the bus to school over the same timed period year (25 percent to 23 percent).[3] Questions from the parent survey were similar to the 2011 program evaluation, but included more focused questions on safety concerns. The 2016 program evaluation also included information on the overall program budget and funding sources from the 2008-2009 school year to the 2015-2016 school year, as well as individual school report cards, documenting the number of

[1] Mode shift calculations included in the 2011 program evaluation were based on data from 32 schools that had both spring 2008 and fall 2011 hand tallies available.

[2] Marin County Safe Routes to Schools Program Evaluation (2011). Transportation Authority of Marin. <http://www.saferoutestoschools.org/documents/TAMSR2SProgramEvaluationwithAppendix-LowRes-112211.pdf>

[3] Mode shift calculations included in the 2016 program evaluation were based on data from 56 schools that returned surveys for both fall and spring semesters.

individual program elements conducted at each school.[4] Limitations of the evaluations include a lack of control schools and no information on which of the program elements and household factors, such as distance to school, were associated with changes in travel behavior.[5]

San Francisco Bay Area, California Climate Initiatives Program Evaluation

As part of their Climate Initiatives Program aimed at reducing greenhouse gas emission, the Metropolitan Transportation Commission (MTC) completed a comprehensive evaluation of the San Francisco Bay region's Safe Routes to School Program and its approximately 669 participating schools. The primary data collection methods for the evaluations were student hand tallies and parent surveys. Overall results from the hand tallies showed a 3 percent increase in the number of students walking to school, a 14 percent increase in the number of students bicycling to school, and a 2 percent decrease in the number of students being driven to school in a family vehicle from the baseline year to follow-up year.[6] MTC found that the number of miles bicycled to school per student per year increased by 2.8 miles and the number of miles driven in a family car decreased by 6.2 miles, resulting in an average reduction of 5.4 pounds of greenhouse gas emissions per student per year.[7] The program evaluation noted that schools that have participated in Safe Routes programs for fewer than two years showed significantly greater increases in active transportation mode shares compared to schools with longer running programs, indicating a decreased rate of effectiveness (diminishing marginal rate of returns).[8]

MTC's Safe Routes to School program evaluation also looked at the effectiveness of individual program elements, parental perceptions, collisions, and other factors with mode shift. Overall, MTC found that specific program elements, including walk and roll programs, walking school buses, bike trains, and National Bike to School Day, were correlated with increases in walking, bicycling, and carpooling; however, the degree to which the programs were effective was unknown because no control schools were included in the program evaluation. MTC also noted that schools offering a greater number and variety of program elements were correlated with increases in walking, bicycling, and carpooling. Results from parent surveys found a positive correlation between students walking or bicycling to school and parents' perceptions that walking and bicycling are fun, important for health, encouraged by their child's school, and something they wished they did more often. The percent of students eligible for free or reduced-price lunches was correlated with higher walk mode share and lower bicycle and carpool mode share. Additionally, family vehicle mode share was correlated with the number of crashes involving bicyclists and pedestrians within a quarter- and half-mile of schools. Limitations of the evaluation include the aforementioned a lack of control schools, an inability to isolate some program elements for evaluation resulting from inconsistent data collection, and varying time periods of evaluation among the program schools.[9]

In addition to Safe Routes to School program evaluation, MTC's Climate Initiatives Program also evaluated other Safe Routes to School, travel demand management (TDM), and bicycle-based programs in the San

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[4] Marin County Safe Routes to Schools Program Evaluation (2016). Transportation Authority of Marin. <http://www.tam.ca.gov/Modules/ShowDocument.aspx?documentid=10155>

[5] Weigand L (2008). A Review of Literature: The Effectiveness of Safe Routes to School and Other Program to Promote Active Transportation to School. Portland State University. <https://www.pdx.edu/ibpi/sites/www.pdx.edu.ibpi/files/Safe%20Routes%20White%20Paper.pdf>

[6] Baseline and follow-up years varied by school, depending on years of participation in the Safe Routes to School program and available data.

[7] MTC noted that if students enrolled in public schools at all nine counties of the San Francisco Bay Area living within a mile of the school received Safe Routes to School programming, it could reduce as much as 1,900 tons of greenhouse gas emissions from transportation due to school trips (extrapolating results to 625,000 public school students).

[8] Climate Initiatives Program Evaluation – Regional Safe Routes to School Program (2016). Metropolitan Transportation Commission.

[9] Climate Initiatives Program Evaluation – Regional Safe Routes to School Program (2016). Metropolitan Transportation Commission.

Francisco Bay Area. The evaluation was designed to estimate the greenhouse gas emission reductions, cost-effectiveness, and societal benefits of each of these programs, in addition to identifying lessons learned to improve to the design and implementation of future programs in the Bay Area. Changes in travel behavior were assessed using surveys administered to program participants and mode share data collected before and after program implementation. In addition to direct changes in travel behavior, the program evaluation also included indirect impacts such as the negative effects of deploying a fleet of vans to recirculate bikeshare bikes. Primarily, projects were evaluated in terms of their impact on greenhouse gas emissions and criteria pollutants, including nitrogen oxides (NOx), reactive organic gases (ROG), and fine particulate matter ($PM_{2.5}$). See **Table 1** for a list of relevant programs in included in the analysis and their costs, estimated benefits, and estimated cost-effectiveness.[10]

The evaluation found that Connect, Redwood City!, a TDM program lead by the San Mateo County Transit District, had the largest impact on greenhouse gas emissions of all of the evaluation programs, reducing an estimated 1,100 to 2,800 tons of greenhouse gas emissions per year or roughly the equivalent of removing 240 to 600 passenger vehicles from the road. Comparatively, the next most effective transportation programs were goBerkeley, a TDM program lead by the City of Berkeley, and the Bay Area School Transportation Collaborative, an educational program lead by the Alameda County Waste Management Authority, which each were estimated to have helped reduce approximately 300 tons of greenhouse gas emissions per year.[11]

[10] Climate Initiative Program – Evaluation Summary Report (2015). Metropolitan Transportation Commission. <http://mtc.ca.gov/sites/default/files/CIP%20Evaluation%20Summary%20Report_7-13-15_FINAL.pdf>

[11] Climate Initiative Program – Evaluation Summary Report (2015). Metropolitan Transportation Commission. <http://mtc.ca.gov/sites/default/files/CIP%20Evaluation%20Summary%20Report_7-13-15_FINAL.pdf>

Table 1: Climate Initiative Program Impacts (MTC, 2015)[12]

Program	Lead Agency	Type	VMT Reduction	GHG Emission Reduction (tons/yr)	Project Cost	Cost Effectiveness ($/ton of CO2e reduced)	ROG (lbs/yr)	NOx (lbs/yr)	$PM_{2.5}$ (lbs/yr)	Active Transportation Benefits	Household Transportation Cost Savings
Connect, Redwood City![13]	San Mateo County Transit District	TDM	3,037,000-7,703,00	1,100-2,790	$921,386	$290-$735	336-857	1,179-3,030	129-333	If the car-share program had not been present, 10% of associated bike trips and 14% of associated walk trips would have been made using a car.	$36 saved/ year/ participant
goBerkeley[14]	City of Berkeley	TDM	918,000	317	$3,100,000	$9,792	169	356	41	-	-
San Francisco Integrated Public/ Private Partnership TDM Program[15]	San Francisco County Transportation Authority	TDM	13,000	5	$858,000	$171,600	2	5	1	-	$0.25/ year/ student or $7,455 total
Bay Area School Transportation Collaborative[16]	Alameda County Waste Management Authority	SRTS	801,000	297	$996,447	$3,355	108	356	36	Sonoma County: Increase bike mode share from 2.8% to 3.4%; Alameda County and San Jose: Increase bike mode share from 1-2% to 4-5% and increase in walk	Sonoma County: $187 saved/ year/ participant; Alameda County and San Jose: $81 saved/ year/ participant

[12] Climate Initiative Program – Evaluation Summary Report (2015). Metropolitan Transportation Commission. <http://mtc.ca.gov/sites/default/files/CIP%20Evaluation%20Summary%20Report_7-13-15_FINAL.pdf>
[13] A package of transportation demand management strategies targeted to residents and employees in Redwood City.
[14] A suite of transportation programs, projects, and policies to better manage parking and travel demand in three neighborhoods in Berkeley.
[15] New public/private partnerships focused on transportation demand management strategies.
[16] Resources to help schools teach students about transportation choices and their impact on the climate.

Program	Lead Agency	Type	VMT Reduction	GHG Emission Reduction (tons/yr)	Project Cost	Cost Effectiveness ($/ton of CO2e reduced)	ROG (lbs/yr)	NOx (lbs/yr)	$PM_{2.5}$ (lbs/yr)	Active Transportation Benefits	Household Transportation Cost Savings
										mode share from 6-8% to 10-14%	
Regional Safe Routes to School[17]	Congestion Management Agencies	SRTS	373,000	210	$10,801,000	$17,124	602	562	22	Students involved in program walked 200,000 miles and biked 150,000 miles more than before the program	-
Green Ways to School[18]	Transportation Authority of Marin	SRTS	212,000	57	$427,046	$7,491	17	61	7	Increase walk mode share by 5%	$26/ student
BikeMobile[19]	Alameda County Transportation Commission	Bike	570,000	201	$565,000	$2,811	183	260	26	74% increase in bikes parked at schools visited by the BikeMobile	$319,342 total or $308/ program participant
Bike-Sharing Pilot Program[20]	Bay Area Air Quality Management District	Bike	314,000	79	$7,000,000	$17,643	37	48	14	San Francisco: 15,914 reduction in peak period vehicle trips; Santa Clara: 1,731 reduction in peak period vehicle trips	-

[17] Funding to five Bay Area county to promote safe walking and bicycling to school.
[18] Resources and technical assistance to help schools teach students about transportation choices.
[19] A large repair and education van that visits schools, recreation centers, and community events providing free bike repair and safety education to promote bike use.
[20] A pilot bike-sharing program with 700 bikes and 70 stations in five Bay Area cities.

Health Evaluation of 10 Safe Routes to School Programs at Low-Income Schools

The Safe Routes to School National Partnership (Partnership) evaluated ten Safe Routes to School programs at low-income schools[21] in California, Georgia, Illinois, Kentucky, Louisiana, Oklahoma, New York, Texas, Virginia, and Washington, D.C. The Partnership collected and analyzed data on the program from the spring of 2008 to the fall of 2009, including data on travel behavior, safety, and air quality around schools. Each site collected student hand tally and parent survey data, with additional caregiver focus groups, safety observations (using protocol developed by UC Berkeley's Safe Transportation Research and Education Center to examine crossing behavior of pedestrians and bicyclists), and vehicles counts at select schools. Finally, the Partnership conducted telephone exit interviews with each school's main program coordinator about the processes of program planning, data collection and implementation, the helpfulness of resources, and the potential sustainability of the program.[22]

An analysis of the parent survey data indicated a modest increase in walking occurred between the baseline and follow-up surveys. The proportion of respondents who reported that their child walked to school was 29 percent higher across all school sites from baseline to follow-up periods. A similar increase in the proportion of students who walked home from school was estimated (26 percent) over the same time period. The changes in walking rates were nearly identical at sites with paid coordinators and those with volunteer coordinators. However, observations from coordinators and student hand tally data contradicted these parental perceptions. School sites with paid coordinators reported over 50 percent more children walking to school and 45 more students walking from school than those with volunteer coordinators. Analysis of student hand tally data by school indicates that even at sites with paid coordinators, the change in walking rates varied. Changes in walking rates at schools with paid coordinators ranged from a 5 percent increase to a 5 percent decrease. Only one site with a volunteer coordinator showed clear increases in walking between baseline and follow-up periods, with the proportion of students walking to school increasing from 7 to 14 percent.[23]

Safety observations looked to track behavior indicative of a change in perceptions of safety conditions for walking and bicycling to school. One school recorded a 63 percent increase in the number of children crossing in, rather than outside of, striped crosswalks. Also, the percent of children crossing with a crossing guard increased 17 percent between the baseline and follow-up periods. Other observations produced few notable results.[24]

Carbon dioxide emission changes were estimated using vehicle volumes and travel distances as a proxy for overall vehicle emission reductions. The Partnership estimated a 1 ton reduction in CO2 emissions at one program school and 11 tons at another program school were travel distance was available.[25]

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[21] Defined as at least 50 percent of students receive free or reduced-price lunches. An additional criterion for school selection was that at least 50 percent of the students live within two miles of the school.

[22] Safe Routes to School Local School Project – A health evaluation at 10 low-income schools. (2010). Safe Routes to School National Partnership. <http://saferoutespartnership.org/sites/default/files/pdf/Health_Evaluation_Feb_2010.pdf>

[23] Safe Routes to School Local School Project – A health evaluation at 10 low-income schools. (2010). Safe Routes to School National Partnership. <http://saferoutespartnership.org/sites/default/files/pdf/Health_Evaluation_Feb_2010.pdf>

[24] Safe Routes to School Local School Project – A health evaluation at 10 low-income schools. (2010). Safe Routes to School National Partnership. <http://saferoutespartnership.org/sites/default/files/pdf/Health_Evaluation_Feb_2010.pdf>

[25] Safe Routes to School Local School Project – A health evaluation at 10 low-income schools. (2010). Safe Routes to School National Partnership. <http://saferoutespartnership.org/sites/default/files/pdf/Health_Evaluation_Feb_2010.pdf>

Limitations in program evaluation include low student hand tally and parent survey response rates for baseline and follow-up periods, ultimately limiting the ability to analyze changes at any one school; a lack of adherence to data collection protocols; and a self-reported lack of time and resources to analyze traffic injury risk, chronic disease, and air quality impacts.[26]

Health Risks and Benefits of Children Walking and Bicycling to School

A 2008 report from UC Berkeley's Safe Transportation Research and Education Center reviewed existing literature on four areas of health that are impacted by children's method of transportation to school: safety, air quality, physical activity, and obesity.[27] The report authors noted a 2002 study on the relative risks of school travel modes using a combination of the Nationwide Personal Transportation Survey, the Fatality Analysis Reporting System, and the National Automobile Sampling System General Estimates System (results shown in **Table 2**).

Table 2: Injury and Fatality Rates per 100 million Student Trips by Mode (1991-1999)[28]

Travel Mode	Mode Share	Injury Rate	Fatality Rate
Walking	12%	310	4.6
Bicycling	2%	1,610	9.6
School Bus	25%	100	0.3
Other Bus	2%	120	0.1
Passenger Vehicle (all drivers)	59%	919	4.4
Passenger Vehicle (adult driver)	45%	490	1.6
Passenger Vehicle (teen driver)	14%	2,300	13.2

The safety analysis found that travel by bus posed the lowest risk of injury or fatality. Walking posed a lower risk of injury than travel by passenger vehicles driven by adults but a higher risk of fatality. Bicycling, though limited in this data set due to a low mode share, had a higher risk of both injury and fatality than all other modes except travel by passenger vehicles driven by teenagers. Over half of school commuting injuries and fatalities were associated with teenage drivers, despite representing only 14 percent of the mode share.[29]

One limitation of this analysis included an inability into account the inverse relationship between the density of children walking and bicycling to school and the relative risk profile of those modes, with the assumption

[26] Safe Routes to School Local School Project – A health evaluation at 10 low-income schools. (2010). Safe Routes to School National Partnership. <http://saferoutespartnership.org/sites/default/files/pdf/Health_Evaluation_Feb_2010.pdf>
[27] Murray L, Orenstein M, Richardson M, and Ragland D. (2008). Health Impacts of the School Commute. SafeTREC. <http://escholarship.org/uc/item/2g612244#page-5>
[28] Murray L, Orenstein M, Richardson M, and Ragland D. (2008). Health Impacts of the School Commute. SafeTREC. <http://escholarship.org/uc/item/2g612244#page-5>
[29] Murray L, Orenstein M, Richardson M, and Ragland D. (2008). Health Impacts of the School Commute. SafeTREC. <http://escholarship.org/uc/item/2g612244#page-5>

that interventions to increase active commuting may decrease the risk faced by students walking and bicycling to school (e.g. “strength in numbers”).[30]

A review of literature on the relationship between air quality and mode of transportation to school found that while students who walk or bicycle to school may be exposed to a higher concentration of harmful pollutants during their commute trip, the detrimental effects of pollutants from motor vehicles on indoor air quality over a longer exposure period do not necessarily present a better alternative.[31]

In addition to air quality benefits, the report authors noted that many active transportation programs promote the health benefits of walking and bicycling to school. They found, that despite the broad support of interventions to increase physical activity through increasing walking and bicycling to school, there was relatively few studies that examined the relationship as of 2002.[32]

Evaluation of Walking School Bus Programs

A 2015 literature review of walking school bus (WSB) programs examined 12 studies to identify their potential to increase children’s physical activity levels or motivation for physical activity. The studies were based on WSB programs in Australia, New Zealand, and the United States between 2001 and 2012 with a wide variety of sociodemographic characteristics of program participants.33 Table 3 summarizes the six studies that measured direct impacts of WSB programs on student physical activity levels, health, and safety awareness.

Four of the studies examined the impact of WSB programs on children’s levels of physical activity, with another focusing indirectly on physical activity as the authors suggested that WSB offer opportunities for children to increase activity levels which, together with changes in diet, could reduce the likelihood of childhood obesity. The authors also aimed to assess the incremental cost effectiveness of a WSB program as an obesity prevention measure if the WSB program was applied throughout Australia, by employing a logic pathway to model the effects on body mass index (BMI) and disability-adjusted life years (DALYs).34 Three of the studies included in the review used randomized, controlled trials, which are often considered to be reliable and rigorous method for testing the efficacy of interventions as they reduce false causality and bias.

Caltrans Benefit-Cost Analysis Tool

Caltrans Active Transportation Program (ATP) consolidates existing federal and state transportation programs into a single program with a focus to provide a mechanism for funding active transportation programs and projects in California. Three cycles of grant funding have been solicited as of 2016, and the grant application for each cycle contained a requirement to conduct a benefit-cost analysis. Cycle 2 grant application requirements asked applicants to test a Caltrans-developed Benefit-Cost Analysis Tool for assessing infrastructure and non-infrastructure projects. While no points were assigned to the outputs of the tool, applicants were asked to provide comments on how to improve the tool. Current limitations

[30] Murray L, Orenstein M, Richardson M, and Ragland D. (2008). Health Impacts of the School Commute. SafeTREC. <http://escholarship.org/uc/item/2g612244#page-5>
[31] Murray L, Orenstein M, Richardson M, and Ragland D. (2008). Health Impacts of the School Commute. SafeTREC. <http://escholarship.org/uc/item/2g612244#page-5>
[32] Murray L, Orenstein M, Richardson M, and Ragland D. (2008). Health Impacts of the School Commute. SafeTREC. <http://escholarship.org/uc/item/2g612244#page-5>
[33] Smith L, Norgate S, Cherett T, Davies N, Winstanley C, Harding M. Walking School Buses as a Form of Active Transportation for Children – A Review of the Evidence. Journal of School Health. 2015 March; 85(3): 197-210. <http://onlinelibrary.wiley.com/doi/10.1111/josh.12239/full>
[34] Moodie M, Haby M, Galvin L, Swinburn B, Carter R. Cost-effectiveness of active transport for primary school children – Walking School Bus Program. International Journal of Behavioral Nutrition and Physical Activity. 2009. 6: 63. <https://ijbnpa.biomedcentral.com/articles/10.1186/1479-5868-6-63>

identified included a need for better source information on the mobility, health, and safety benefits of non-infrastructure projects and more detailed information on specific non-infrastructure projects. Cycle 1 and Cycle 3 grant applications asked applicants to conduct a benefit-cost analysis using an approach of their choosing.

Caltrans is currently in the process of incorporating pedestrian and bicycle infrastructure projects into its more robust California Life-Cycle Benefit/Cost Analysis Model (Cal-B/C). The incorporation of non-infrastructure active transportation projects is not anticipated to be included in the update of Cal-B/C; however, Caltans' Office of Transportation Economics will consider incorporating non-infrastructure projects into the tool if reliable and validated data sources are identified

Table 3: Walking School Bus Studies[35]

Study	Study Length, Location, and Participants (I/C)	Purpose	Method	Evidence	Limitations
Heelan et al. (2009)[36]	2 years; Nebraska (two intervention and one control schools); 324 students (201/123)	Primary: Evaluate school-wide prevalence of walking to school. Secondary: Objectively compare physical activity levels among subsample of research participants and frequency of walking school bus activities.	Primary: Self-reported student survey over six time periods (fall, winter, spring). Secondary: Accelerometer data during four time periods and baseline and follow-up body mass index.	Primary: 27% higher prevalence of walking to school among intervention schools. Secondary: Significantly higher levels of physical activity among intervention group compared to control group (78.0 [38.9] v 60.6 [27.7] minutes/day, p < .05). Frequent walkers obtained 25% more physical activity (P < .05), gained 58% less body fat (P < .05), and attenuated BMI by 50% (P < .05) compared with passive commuters.	Prevalence of walking to school measured by self-report, potentially limiting validity of study. Accelerometer data only for subsample.
Mendoza, et al. (2009)[37]	1 year; Washington (one intervention school and two control schools in urban, disadvantaged area); 820 students (347/293)	Primary: Evaluate school-wide prevalence of walking to school. Secondary: Evaluate school-wide prevalence of riding	Self-reported student survey at four time periods (baseline, 1-month, 6-month, and 12-month follow-up)	Primary: There was no statistically significant difference in the number of students walking to school between the control and intervention schools during the baseline period, however, at 1-month, 6-month, and 12-month follow-up periods, a higher proportion of students walked to	Non-random selection of schools; self-reported travel mode data; small sample size.

[35] Smith L, Norgate S, Cherett T, Davies N, Winstanley C, Harding M. Walking School Buses as a Form of Active Transportation for Children – A Review of the Evidence. Journal of School Health. 2015 March; 85(3): 197-210. <http://onlinelibrary.wiley.com/doi/10.1111/josh.12239/full>
[36] Heelan KA, Abbey BM, Donnelly JE, Mayo MS, Welk GJ. Evaluation of a walking school bus for promoting physical activity in youth. Journal of Physical Activity and Health. 2009 Sep; 6(5):560-567. <https://www.ncbi.nlm.nih.gov/pubmed/19953832>
[37] Mendoza JA, Levinger DD, Johnston BD. Pilot evaluation of a walking school bus program in a low-income, urban community. BioMed Central Public Health. 2009 May; 9:122/ <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2680829/>

Study	Study Length, Location, and Participants (I/C)	Purpose	Method	Evidence	Limitations
		in a car or taking the bus to school.		school at the intervention school versus the control schools. Secondary: There was no significant difference in transport by car or school bus between the intervention and control schools at each of the assessment time points (bicycling and riding the city bus were infrequent methods of transports at all study schools).	
Mendoza, et al. (2011)[38]	5 weeks; Texas (four intervention schools and four control schools); 149 students (70/79)	Primary: Evaluate school-wide prevalence of walking and bicycling to school. Secondary: Evaluate school-wide physical activity levels.	Pilot randomized controlled trial with random allocation of treatment (one to three walking school buses with trained staff) and control conditions at eight schools measured at two time periods (pre-study and during weeks four or five of the study). Primary: Daily questionnaire on mode of transportation to school. Secondary: Accelerometer data worn for at least 10 hours during week one and weeks four or five.	Primary: Intervention students increased active commuting from 23.8 percent +/- 9.2% pre-study to 54% +/- 9.2% during weeks four or five, compared to control students from 40.2% +/- 8.9% to 32.6% +/- 8.9%. Secondary: Intervention students increased minutes of daily moderate-to-vigorous physical activity from 46.6 +/- 4.5 to 48.8 +/- 4.5, compared to control students who decreased from 46.1 +/- 4.3 to 41.3 +/- 4.3/	Brief intervention period limited generalizability; self-reported travel mode data.
Mendoza, et al. (2012)[39]	5 weeks; Texas (four intervention schools and four control	Primary: Evaluate changes to pedestrian safety behaviors, such as	Pilot randomized controlled trial with random allocation of treatment (one to three walking school buses with trained staff)	Primary: Intervention students had five-fold higher odds of crossing at	Cross-sectional school-level data of pedestrian behavior of children of any grade and not longitudinal data on just Walking School Bus

[38] Mendoza JA, Watson K, Baranowski T, Nicklas TA, Uscanga DK, Hanfling MJ. The Walking School Bus and Children's Physical Activity: A Pilot Cluster Randomized Controlled Trial. Pediatrics. 2011 Sep; 128(3): e537-e544. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3164094/>

[39] Mendoza JA, Watson K, Chen TA, Baranowski T, Nicklas TA, Uscanga DK, Hanfling MJ. Impact of a pilot walking school bus intervention on children's pedestrian safety behaviors: a pilot study. Health Place. 2012 Jan; 18(1): 24-30. <http://www.sciencedirect.com/science/article/pii/S1353829211001201>

Study	Study Length, Location, and Participants (I/C)	Purpose	Method	Evidence	Limitations
	schools); 149 students (70/79)	school-level street crossing	and control conditions at eight schools measured at two time periods (pre-study and during weeks four or five of the study). Primary: 1,252 pedestrian safety behavior observations during pre-study period and 2,548 observations during weeks four or five (crossed at a corner or crosswalk, crossed with an adult or safety patrol, stopped at the curb, looked left-right-left, and walked and did not run across the street.	corner crosswalk but five-fold lower odds of stopping at the curb.	participants, potentially diluting the impact at intervention schools.
Moodie, et al. (2009)[40]	1 year; Victoria, Australia; modeled 7,840 children aged 5 to 7 years	Primary: Evaluate societal perspective on the effects of BMI and DALYs if Victorian Walking School Bus program was applied throughout Australia.	Primary: Logic pathway to model effects on BMI and DALYs. Cost offsets and DALY benefits were modeled until the eligible cohort reached 100 years of age or death, with a reference year of 2001. Secondary: Second stage filter criteria (equity, strength of evidence, acceptability, feasibility, sustainability, and side-effects) were assessed to incorporate additional factors that impact on resource allocation decisions.	Primary: Incremental saving of 30 Disability-Adjusted Life Years (DALY) and a net cost per DALY saved of $AUD 0.76 million. Under the current modeling assumptions, the Walking School Bus program was not an effective or cost-effective measure to reduce childhood obesity.	The evidence base was judged as 'weak' as there was no data available documenting the increase in the number of children walking due to the intervention. Reports of missing data for 7 of 33 local governments with Walking School Bus programs may have resulted in an underestimation of program activity.

[40] Moodie M, Haby M, Galvin L, Swinburn B, Carter R. Cost-effectiveness of active transport for primary school children – Walking School Bus Program. International Journal of Behavioral Nutrition and Physical Activity. 2009. 6: 63. <https://ijbnpa.biomedcentral.com/articles/10.1186/1479-5868-6-63>

Study	Study Length, Location, and Participants (I/C)	Purpose	Method	Evidence	Limitations
Sirard, et al. (2008)[41]	1 week; Menlo Park, California; 11 students 95/6)	Test feasibility of Walking School Bus as strategy to increase physical activity from walking to school.	Randomized, controlled trial using Acti-Graph monitors for 14 consecutive days (7 days baseline and 7 days study) and accelerometers (7 study days)	Unknown.	Small sample size over short time period.

[41] Sirard JR, Alhassan S, Spencer TR, Robinson TN. Changes in physical activity from walking to school. J Nutr Educ Behav. 2008 Sep-Oct; 40(5): 324-326. <https://www.ncbi.nlm.nih.gov/pubmed/18725153>

Program Costs

In addition to understanding the impacts of active transportation programming, the capital and ongoing operations costs must be considered for evaluating the effectiveness of proposed programs. While documentation on the costs of active transportation programs are more readily available, individual program costs vary by program type, size, frequency, intensity, location, and level of coordination. Using data from the existing Safe Routes to School programs in the San Diego region, **Table 4** shows a range of start-up and on-going cost estimate for a typical Safe Routes to School program. These costs estimates are broken into four scenarios to represent the range of program types:

A. Existing Support
   - Regional agency supports commuter program
   - Safe Routes to School Coalition convenes regional and local agencies, implementers, and champions
   - Safe Routes to School funding is incorporated into regional projects
   - Local jurisdictions apply for grant funding based on interest and capacity
   - City staff may coordinate Safe Routes to School projects and programs
   - School-based activities depend on school champions, who may be school volunteers, PTA, school districts, and/or other partners.

B. Regional Coordination
   - Regional entities develop resources potentially through a commuter program
   - Regional entities facilitate coordination between local program and strengthen the Safe Routes to School Coalition's role regionally
   - Safe Routes to School funding is incorporated into regional projects
   - Local jurisdictions apply for grant funding based on interest and capacity
   - School-based activities depend on school champions, who benefit from regional resources and coordination

C. Regional Coordination & High Needs Assistance
   - Regional entities develop additional resources and coordinate between local programs
   - A regional agency funds Safe Routes to School activities in high-needs areas, while other areas benefit from regional resources and grant funding
   - Safe Routes to School funding is incorporated into regional projects
   - Local jurisdictions may apply for additional funding
   - High-needs schools receive staff support for school-based activities
   - Other school-based activities depend on school champions who benefit from regional resources and coordination

D. Regional One-on-One Assistance
   - A regional agency administers the countywide Safe Routes to School program
   - A regional entity develops resources and facilitates coordination between local programs
   - Contractors work with local jurisdictions and school districts to implement program elements
   - High-needs schools are prioritized, as well as geographic equity

The average cost of Safe Routes to School programming per school ranges from $2,000 to $30,000 depending on the level of intensity of the programming needed. Applied to California's roughly 10,000 public schools, this would result in statewide programming costs between $20,000,000 and $300,000,000.

Table 4: Estimated Active Transportation Program Costs[42]

Program Element			Regional Program Costs	Total Program Costs	Costs per School	Estimated State-wide Costs (10,000 schools)
(A) Existing Support	Low	Start-up	$41,000	$49,500	$30,000	$300,000,000
		On-going	$8,500			
	Medium	Start-up	$91,500	$102,000	$30,000	$300,000,000
		On-going	$10,500			
	High	Start-up	$87,000	$98,000	$30,000	$300,000,000
		On-going	$11,000			
(B) Regional Coordination	Low	Start-up	$42,000	$49,500	$2,000	$20,000,000
		On-going	$7,500			
	High	Start-up	$159,000	$177,000	$2,000	$20,000,000
		On-going	$18,000			
(C) Regional Coordination & High Needs Assistance	Low	Start-up	$59,000	$69,000	$7,000	$70,000,000
		On-going	$10,000			
	Medium	Start-up	$98,000	$113,000	$8,000	$80,000,000
		On-going	$15,000			
	High	Start-up	$160,000	$175,000	$9,000	$90,000,000
		On-going	$15,000			
(D) Regional One-on-One Assistance	Low	Start-up	$40,000	$48,000	$15,000	$150,000,000
		On-going	$8,000			
	Medium	Start-up	$98,000	$118,000	$21,000	$210,000,000
		On-going	$20,000			
	High	Start-up	$161,000	$193,000	$23,000	$230,000,000
		On-going	$32,000			

[42] Regional Safe Routes to School Implementation Framework Project. (2014). San Diego Association of Governments.

Discussion

To date, no comprehensive study exists that evaluates the effectiveness of active transportation programs, limiting the ability to incorporate existing and planned programming into benefit-cost analyses or other tools and preventing an "apples-to-apples" comparison to infrastructure projects. This is in large part due to the large number of potential programs available, as well their varying size, frequency, intensity, location, and level of coordination. Large-scale program evaluations, such as Marin County's Safe Routes to School program evaluation or MTC's Regional Safe Routes to School program evaluation, demonstrate the non-uniform impacts of programs on mode shift, and subsequently the large variation in physical activity levels, student health, safety, and air quality. More detailed analyses of the health impacts of Safe Routes to School programming conducted by the National Safe Routes to School Partnership and UC Berkeley's SafeTREC offer more detailed and generalizable estimates of mode shift and collision risk factors, respectively; however, they also help highlight the wide range of impacts at schools based on the presence of a paid or volunteer program coordinators and the frequency of program offerings. Recent Walking School Bus program evaluations offer the most rigorous studies of active transportation programs, and while the evaluations have limited sample sizes, they demonstrate defensible approaches to evaluating active transportation programs. Specifically, these analyses include a combination of self-reported data and empirical data, make use of control schools, and, in some cases, are designed as randomized, control trials. Incorporating these evaluation tools into larger Safe Routes to School program evaluations or other specific program element evaluations will help provide Caltrans with a more robust and reliable data set off which to model the benefits of active transportation programs. One approach for encouraging more robust data collection on programs would be replacing the benefit-cost requirements in Active Transportation Program applications with "bonus" points for developing rigorous program evaluation methods or partnering with researchers.

3. Infrastructure Evaluation

Bicycle Networks

To achieve the goal of tripling the bicycling across the State of California, the extent and quality of the bicycle network needs to be improved. There is ample research exploring the relationship between bicycle infrastructure and rates of bicycling which suggests that higher rates of bicycling are associated with denser networks of bicycle facilities. Two papers in particular have looked at cities nationally to establish this relationship, which will be discussed now.

Dill and Carr (2003) look at the relationship between bicycle commuting, bicycle facility mileage, population density, state-level spending per capita on bicycle and pedestrian projects, and other contextual variables as controls for a sample of 35 U.S. cities[43]. The areal density of Class 2 bike lanes is found to be a significant predictor of bicycle commute rates.

Schoner and Levinson (2014) perform a more detailed analysis of bicycle facility networks in a study of 74 U.S. cities[44]. They calculate a series of network structure measures describing the bicycle lanes and paths in each of these cities. These measures are then reduced using factor analysis to 5 network characteristics, which the authors describe as “size”, “connectivity”, “density”, “fragmentation”, and “directness”. The factors are then tested as predictors for bicycle commuting, both on their own and in a model with controls for sociodemographics. In both models, network density is found to be the most significant predictor of bicycle commuting, although network connectivity, fragmentation, and directness also appear to have effects. In the controlled model, the only variable with a significant effect is the percentage of the population comprised of college students.

Schoner and Levinson’s research suggests that network density is the most significant and highest impact network characteristic for predicting bicycle commute mode share. Accordingly, we look at a sample of cities around California to see how their existing networks compare against the sample in Schoner & Levinson to develop an approximate level of investment needed to achieve the stated mode share goals.

Dataset Construction

We collected data from cities around California to establish a baseline for current levels of bicycling and infrastructure availability. For each city, we collected:

- Population
- Size (mi^2)
- Miles of multi-use paths
- Centerline miles of bicycle lanes
- Bicycle commute mode share (American Community Survey)

Most of this data is readily available from the census. However, as noted in the Baseline Data Methodology paper, there is not currently a centralized database of pedestrian or bicycle infrastructure data. Our network data estimates come from a variety of sources, listed here by order of preference:

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[43] Dill, J and Theresa C. “Bicycle commuting and facilities in major US cities: if you build them, commuters will use them.” Transportation Research Record: Journal of the Transportation Research Board 1828 (2003): 116-123.

[44] Schoner, JE and DM Levinson. “The missing link: bicycle infrastructure networks and ridership in 74 US cities.” *Transportation*, 41(6), 1187-1204.

- The Alliance for Biking and Walking's Annual Benchmarking Report[45].
- Bicycle master plans/Active transportation plans completed within the past 3 years
- Regional bikeway network GIS datasets

This data collection method was intended to efficiently gather rough estimates for a broad set of communities across the state. Using this approach, we summarized the bicycle networks for 99 California cities, covering 44% of the state's population and 16.5 million square miles in total.

Analysis Methods

To estimate the bikeway network needed to support a tripling of the bicycle mode share, we consider the effects on mode share suggested by Schoner & Levinson's model of increasing bikeway density. Specifically, Schoner & Levinson find a multiplier effect of 77% mode share associated with each standard deviation increase in the network density. Their sample's network density measures have a mean of 1.74 kilometers per square kilometer and a standard deviation of 2.67 kilometers per square kilometer. Assuming the linear model used in the paper, this suggests that each density increase of 2.67 kilometers per square kilometer would be associated with a 77% point increase in the bicycle commute mode share.

We then propose two investment allocation scenarios to determine what the impacts on overall statewide mode share might be for a range of levels of investment. These scenarios are:

- Allocation based on land area (i.e. uniform distribution of bike infrastructure across the state)
- Allocation based on population (i.e. per capita allocation)

For each scenario, we test the expected mode share under a range of levels of investment. The amount of investment is quantified as the percentage increase in bikeway mileage. How these investments get

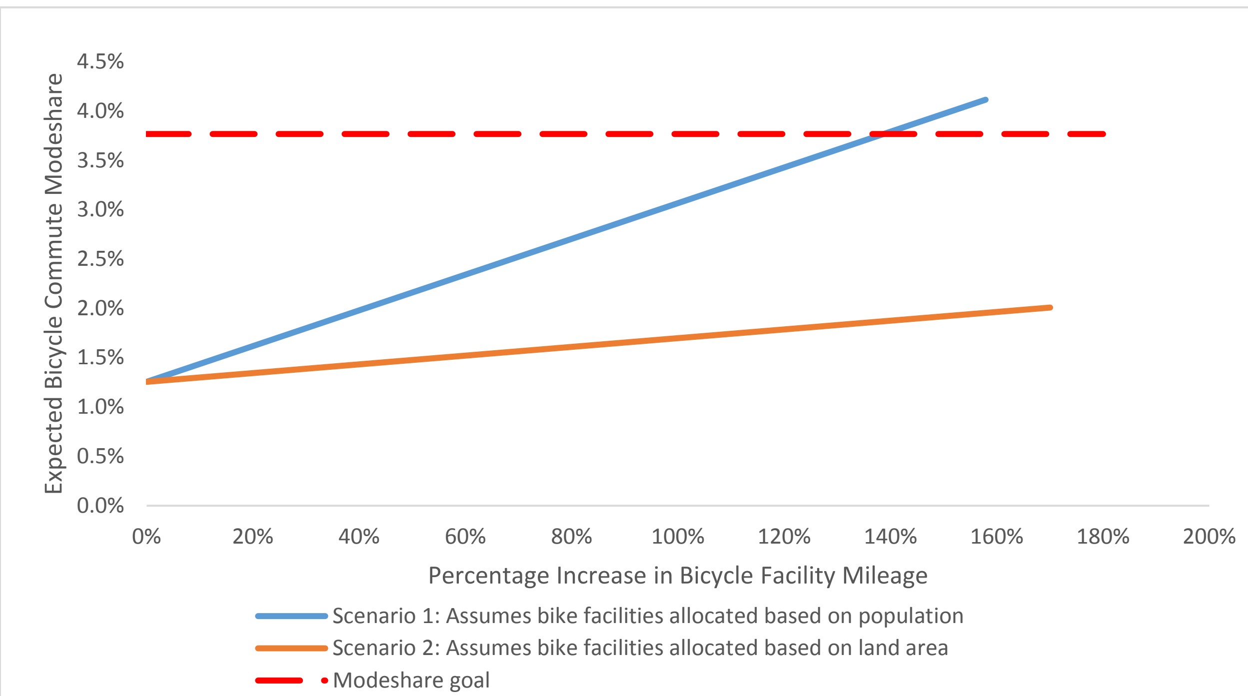

Figure 1: Estimated bicycle mode share effects of bicycle facility construction

[45] Alliance for Biking & Walking. "Bicycling & Walking in the United States: Benchmarking Report 2016." <http://www.bikewalkalliance.org/storage/documents/reports/2016benchmarkingreport_web.pdf>

allocated between cities and towns across the state has an impact on the anticipated mileage need to achieve a statewide mode shift goal. The results of this analysis are shown in Figure 1.

The expected mode share shown here corresponds to the sample cities, which currently have an overall bicycle commute mode share of 1.3%, which is slightly higher than the statewide share of 1.1%. Assuming growth in cycling happens in proportion to population, tripling the statewide bicycle mode share would require a sample mode share of 3.77%, which is depicted with the dashed horizontal red line. As can be seen, it is anticipated that building bikeways on a per capita basis would be more effective at achieving the network coverage needed for a tripling of the bicycle mode share, and this would be achieved by increasing the bicycle facility mileage by approximately 130%.

The following assumptions are made to determine a cost estimate for this full build-out scenario:

- The current ratio of bike lane mileage to multi-use path mileage will be maintained, or in other words the network structure will be similar to existing.
- Bicycle lanes are estimated to cost a median $133,170 per lane-mile ($266,340 per centerline mile) with a low end estimate of $10,720/centerline mile and a high end estimate of $500,000/centerline mile[46][47], and multi-use paths are assumed to cost a median $481,140 per mile with a low-end estimate of $129,420/mile and a high-end estimate of $1,500,000/mile[48].
- Construction costs are uniform across the state.

Based on these assumptions, we estimate a total statewide cost for increasing the existing bikeway network by 140% at a median of $4.32B with a lower bound of $1.28B and an upper bound of $10.3B.

The California Bicycle Coalition also developed an estimate for the cost to construct the infrastructure necessary to support a tripling of California's bicycle mode share by 2020, using different methods than we have used here. Their estimate for a statewide network buildout is approximately $8B, which agrees well with our estimates[49].

Pedestrian Networks

To approximate the budget required to upgrade the pedestrian network statewide, we consider two recent settlements in which California agencies have committed budget to improve their sidewalk systems for ADA compliance. Caltrans has agreed to spend $1.1B over 30 years on ensuring that all pedestrian assets are accessible.[50] The lawsuit cites 2,500 sidewalk miles of retrofits that will be targeted, which yields a retrofit cost of $880,000 per centerline mile. Alternatively, we could assume that this budget is allocated across Caltrans' non-limited access highways, which total approximately 14,000 centerline miles, we estimate a cost to retrofit of approximately $78,500 per centerline mile. In a similar settlement, the City of Los Angeles

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[46] Bicycle Lanes. Pedestrian and Bicycle Information Center. <http://www.pedbikeinfo.org/planning/facilities_bike_bikelanes.cfm>

[47] Weigand, L., N. McNeil, and J. Dill. "Cost Analysis of Bicycle Facilities: Cases from cities in the Portland, OR region". Portland State University, 2013. <http://activelivingresearch.org/sites/default/files/Dill_Bicycle_Facility_Cost_June2013.pdf>

[48] Shared-Use Paths/Sidepaths. Pedestrian and Bicycle Information Center. < http://www.pedbikeinfo.org/planning/facilities_ped_paths.cfm>

[49] California Bicycle Coalition. "How California's bike budget can triple bicycling by 2020, and why it's a great idea and how much it will cost."

[50] DeSio, Mark. "Caltrans, Disabled Rights Advocates Applaud Agreement to Improve Access to Pedestrian Facilities for the Disabled." Caltrans News Release December 22, 2009. <http://www.dot.ca.gov/hq/paffairs/news/pressrel/09pr28.htm>

committed $1.3B to pedestrian accessibility upgrades on its municipal network[51]. The non-freeway mileage network in Los Angeles totals approximately 7,400 centerline miles, leading to an approximate cost of $190,000 per centerline mile.

California's non-limited access, non-Federal aid road network totals approximately 324,000 centerline miles. Assuming that the above rates apply across the entire network yields a high estimate of $285B based on the Caltrans settlement's 2500 miles estimate, a low estimate of $25B based on applying the Caltrans settlement amount across the full SHS system and a mid-point estimate of $61B based on the Los Angeles estimate.

[51] Reyes, Emily Alpert. "L.A. agrees to spend $1.3 billion to fix sidewalks in ADA case." Los Angeles Times, April 1, 2015. <http://www.latimes.com/local/lanow/la-me-ln-lawsuit-broken-sidewalks-20150331-story.html>.