INCREASING WALKING, CYCLING, AND TRANSIT: IMPROVING CALIFORNIANS' HEALTH, SAVING COSTS, AND REDUCING GREENHOUSE GASES

FINAL REPORT

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Increasing Walking, Cycling, and Transit Could Significantly Improve the Health of Californians, Save Billions in Health Care Costs, and Reduce Greenhouse Gases

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PURPOSE

California legislation and policy promote strategies to lower transportation-related greenhouse gas (GHG) emissions by reducing vehicle miles traveled (VMT). An important component of VMT reduction is promoting active transportation - walking and bicycling. Active transportation increases physical activity, which improves population health by reducing risks of heart disease, stroke, diabetes, dementia, depression, and some types of cancers. In 2010, more than 23,000 deaths could be attributed to physical inactivity in California. This research asked:

- How many deaths could be avoided and how many years of life could be gained if Californians: a) doubled their walking and transit trips and tripled their cycling, and b) further increased biking and walking to meet the U.S. Surgeon General recommendations for physical activity?
- What would the economic impact of improved public health due to increased physical activity be under these scenarios?
- What would the impact on GHG emissions be?

METHODS

Using data from California travel and health surveys, vital statistics, collision databases, and regional and statewide travel models, the Integrated Transport and Health Impacts Model (ITHIM) estimated the number of deaths and years of life lost, disability, economic, and greenhouse gas emission outcomes if the 2010 California population met ambitious mobility and health goals.

FINDINGS

- California achieving its stated goals of doubling walking and transit trips and tripling bicycling by 2020 would annually eliminate 2,348 annual deaths from chronic diseases, but add 254 deaths from traffic collisions – overall leading to 2,095 fewer deaths and 30,124 fewer years of life lost and disability.

- In an optimum health scenario that increases active transport for a typical Californian to 21.4 minutes per day – a level recommended by the U.S. Surgeon General – California could experience 8,057 fewer annual deaths and 142,101 fewer years of life lost and disability.
- The annual value of preventing premature deaths and disability ranged from $1 billion to $15.5 billion for the mobility scenario of doubling walking and transit trips and tripling bicycling, and $5.7 to $59.6 billion for the optimum health scenario, depending on the method of monetizing deaths and disability.
- Assuming half the increases in active transport are offset by less car travel, annual car carbon emissions would decline between 3% to 14% compared to the 2010 baseline over the range of scenarios.

CONCLUSIONS

This study, like the majority of health impact studies of active transport in the United States and Europe, shows that physical activity due to increased biking and walking would have a profound impact on health and economic outcomes while contributing to State GHG and VMT reduction goals. Reducing the risk of traffic injuries is imperative. Active transport significantly builds on the positive health impacts from other transportation-related GHG mitigation strategies whose health co-benefit is improved air quality.

Achieving mobility and health goals would constitute a major public health accomplishment on par with California's successful efforts at tobacco control.

TECHNICAL ABSTRACT

BACKGROUND: California legislation and policy promote land use strategies that mitigate transportation-related greenhouse gas emissions by reducing vehicle miles traveled (VMT). These strategies also promote active transportation - walking and bicycling alone, and combined with transit trips--which, through increased physical activity, improves population health. The health benefits and harms of specific State of California goals for active transportation have not been quantified on a regional and statewide basis, nor have their potential for health cost savings and carbon mitigation. This report provides an analysis of the health benefits and harms of achieving the mobility-based goals of the CA Department of Transportation Strategic Management Plan (CSMP) and health-based goals of the U.S. Surgeon General (USSG).

METHODS: Using data from California travel and health surveys, vital statistics, collision databases, and outputs from regional and statewide travel models, the Integrated Transport and Health Impacts Model (ITHIM) estimated the change in the population disease burden, as measured by deaths and disability adjusted life years (DALYs), due to a shift from a 2010 baseline travel pattern to four alternatives. Health pathways modeled were physical activity and road traffic injuries. ITHIM incorporates specific chronic diseases that have strong evidence from systematic reviews of a dose-response gradient for physical activity. These include cardiovascular diseases, colon cancer, breast cancer, diabetes, depression, and dementia. The CSMP2020 scenario envisions a doubling of 2010 baseline levels of walking and transit and a tripling of bicycling by 2020. In the AT2030 scenario, walking and transit quadruple from 2010 baseline levels and bicycling increases 9-fold by 2030. The third scenario is based on levels of physical activity from active transport achieved by half the California population meeting the U.S. Surgeon General's physical activity recommendation of 150 weekly minutes of moderate physical activity (USSG1.0). The fourth scenario would achieve 75 weekly minutes by at least half of the California population. In all scenarios it was assumed that half the increase in active travel would replace car trips.

RESULTS: From a baseline per capita mean of 40.5 minutes of active travel per week, scenarios increased active travel from 84.5 to 277 minutes per week, which is approximately the duration of the average California commute in 2010 considering all modes. The annual number of deaths progressively decreased with increasing levels of active transport: -2,095 for CSMP2020 and -8,057 for USSG1.0. In each scenario, chronic disease reductions were accompanied by increases in the absolute number of serious and fatal road traffic injuries, despite reduced injury risks per mile traveled. The annual monetized value of health outcomes through chronic disease reduction were significant, ranging from 1.0 to 59.6 billion dollars, depending on the method of monetization. Holding population and carbon dioxide emissions factors constant at 2010 levels, active transport scenarios were associated with carbon reductions of 3% (CSMP2020) to 14% (USSG1.0).

CONCLUSIONS: There are large health benefits associated with achieving State active transportation targets. Significant carbon mitigation may also be achieved if increases in active travel are accompanied by concomitant decreases in car travel. Active travel generates reductions in chronic disease, and the overall health benefits (and avoided health harms from increased traffic injuries) depend on efforts made to control of road traffic injuries, which are substantially influenced by both active travel mode share and car mile substitution. Achieving mobility- or health-based goals would constitute a major public health achievement on par with California's successful efforts at tobacco control.

INTRODUCTION

California legislation and executive orders call for scheduled reductions in greenhouse gas (GHG) emissions to counter climate change.[1-4] Increased reliance on renewable energy, electrification of the vehicle fleet, lowering the carbon intensity of transportation fuels, and land use that promotes compact development and location-efficient housing are strategies that aim to minimize the combustion of fossil fuels, decrease vehicle miles traveled (VMT), and improve air quality.[5, 6]

Legislation (SB743) was passed in 2013 that intended to balance the needs of congestion management with statewide goals to promote infill development, public health through active transportation, and reduction of GHG emissions. SB743 created incentives for compliance with the California Environmental Quality Act (CEQA), provided that proposed projects reduce GHG emissions, develop multimodal transportation networks, and diversify land uses.[7] This replaced criteria that elevated traffic congestion as a significant impact. The Governor's Office of Planning and Research (OPR) was charged with recommending metrics to assess transportation impacts of infill projects, including VMT and VMT per capita.

Strategic planning documents, such as the State's *Scoping Plan*[6] for meeting California GHG emission reductions targets, acknowledge that compact development may enhance active transportation (walking and cycling combined with transit), which has documented health benefits through increased physical activity and decreased air pollution, but may have potential harms through increased risks of road traffic injury.[8-11] The health benefits and harms of specific State of California goals for active transportation have not been quantified on a regional and statewide basis, nor have their potential for health cost savings and carbon mitigation.

This report fills this information gap by providing an analysis of the health benefits and harms of achieving the mobility-based goals of the California Department of Transportation (Caltrans) Strategic Management Plan, 2015–2020[12] and health-based goals of the U.S. Surgeon General,[13] which have been widely adopted by federal and California health agencies[14] as well as the medical and public health community.

METHODS

Study Population

The study included the 2010 residential population of the five largest California transportation planning regions: San Francisco Bay Area, Sacramento Area, San Joaquin Valley, Southern California, and San Diego County. These regions comprised 30 of California's 58 counties, and make up 97% of the state's population. Rural counties, mostly in the north, east, and central coast, did not have statistically reliable health or travel data, and were excluded from analysis.

Model and Health Outcomes

Previous research has identified physical activity, air pollution, and traffic injuries as the main, direct pathways of transportation-related health co-benefits and harms.[10] The

Integrated Transport and Health Impact Model (ITHIM, Figure 1) estimates the change in the population disease burden due to a shift from a baseline travel pattern to an alternative. The approach and application to transport and health have been described previously.[9, 11, 15-17]

In brief, the model incorporates an extension of the population attributable fraction (PAF), which is used in public health to describe the percent of disease or injury that could be avoided in a population by eliminating a risk factor such as lack of physical activity. The population burden of disease was measured in deaths and disability adjusted life years, DALYs, which are the sum of years of life lost due to premature mortality and years of living with disability. Deaths and DALYs were obtained from the 2010 U.S. Global Burden of Disease (GBD).[18] To account for local geographic variation, age-, sex-, and cause-specific deaths and DALYs for each California region were adjusted by the ratio of their counties' and U.S. mortality rates. The population attributable fraction was estimated from exposure-response relationships between a) the risk factor – physical activity, fine particulate matter ($PM_{2.5}$), road traffic injuries – and the health outcome for specific causes, and b) the exposure distribution of the risk factor in the baseline population and in the alternative. ITHIM incorporates specific chronic diseases that have strong evidence from systematic reviews of a relative risk (RR)-exposure gradient for physical activity. These include cardiovascular diseases (ischemic heart disease, hypertensive heart disease, and cerebrovascular disease), colon cancer, breast cancer, diabetes, depression, and dementia.

Physical activity encompasses both active travel and non-travel related physical activity, including leisure and occupational activities. Daily or weekly activity times were multiplied by weights to give metabolic equivalent task (MET) hours[19], which reflect energy expenditures for walking and bicycling at average speeds and for leisure activities and occupational tasks.

For traffic injuries, a distance-based model was used. Injuries were estimated by multiplying change in miles traveled of one or more parties to a collision for each pairwise combination of victim and striking vehicle (pedestrian, bicyclist, motorcycle, car, bus, truck) by the baseline rate per mile traveled for injuries of that combination of modes. (The car category includes personal passenger vehicles: automobiles, vans, and light duty trucks.) A square root function was applied to travel miles to account for the observation that pedestrian and bicyclist injuries tend to be lower at higher mode shares – i.e., "safety-in-numbers".[20] Injury risks were stratified by severity (fatal, serious) and roadway type (local, arterial, and highway), which indirectly takes into account the role of speed and traffic volume in traffic injuries.

Data on air pollution were only available for the Bay Area region. Automobile emissions of primary and secondary constituents of fine particulate matter were first estimated for baseline automobile vehicle miles traveled and alternative scenarios. Aggregate emissions were inputs to an air shed model[21] that took into account meteorology, mobile and stationary source emissions, and chemical and photochemical reactions to predict county population-weighted average air concentrations of $PM_{2.5}$ for the Bay Area.

Monetized Value of Health Outcomes

ITHIM incorporates two widely applied approaches in the health economics literature for estimating the cost of illness, the value of lives and years of life saved or lost.[22, 23] The Cost of Illness (COI) method calculates direct and indirect costs of illness. Direct costs typically include hospital inpatient stays, emergency room visits, hospital outpatient care, primary care, specialty care, home healthcare, and prescription medications. Indirect costs usually include loss of productivity due to premature mortality and/or illness. National cost of illness studies were identified for the diseases modeled in ITHIM, and national costs in constant 2010 dollars were scaled to California regions. The change in monetized health outcomes from baseline to a scenario were calculated by multiplying the population attributable fraction and the regional cost, which was summed for the five study regions for the statewide total. The Willingness to Pay (WTP) method describes the maximum amount of money an individual is willing to pay to cure or decrease the risk of death or injury, and can take into account pain and suffering, lost leisure time, and lost wages.[24] The value of a statistical life based on WTP is defined by the U.S. Environmental Protection Agency as the economic value placed on eliminating the risk of one premature death.[25] The costs estimated by this method are simply the change in the number of deaths times the value of a statistical life, $7.4 million. Additional detail is presented elsewhere.[26]

Baseline Travel Distances and Times

Per capita mean daily distances for walking, bicycling, and motorcycling were calculated from travel diaries, and person and household data in the 2012 California Household Travel Survey (CHTS).[27] Mean per capita daily vehicle miles traveled (VMT) for cars and trucks were calculated from trip list outputs of regional activity-based and 4-step travel demand models (San Francisco Bay Area, Southern California, and San Joaquin Valley) and the California Statewide Travel Demand Model (Sacramento Area and San Diego County).[28] For the Sacramento Area and San Diego County, per capita mean daily personal miles traveled for cars and buses were based on CHTS. For motorized modes, the percentage of VMT by roadway type was obtained from the fully loaded networks of the travel models. It was assumed that 75% of walking occurs on local roads and 25% on arterials, and that 53% of bicycling occurs on local roads and 47% on arterials.[29]

Carbon Emissions

Aggregate carbon emissions from cars and light trucks were estimated for each California region from modeled emission factors (g CO_2eq mi^{-1}) in 2010.[30] The EMFAC model takes into account the characteristics of the vehicle fleet, fuel type (gasoline, diesel, and electric), and operating conditions. The emission factor in 2010 was multiplied by per capita car VMT and the 2010 California population.

Scenarios

Travel patterns for four scenarios were based on state and national goals reflecting ambitious increases in active travel from regional baselines. The California Department of Transportation (Caltrans) Strategic Management Plan (CSMP) 2015-2020 targets a doubling of 2010 baseline levels of walking and transit and a tripling of bicycling by 2020 (CSMP2020).[12] Maintaining this rate of increase of active travel from 2020 to 2030 suggests another scenario of quadrupling 2010 baseline levels of walking and transit and a nine-fold increase in baseline levels of bicycling by 2030 (AT2030). The third scenario is based on levels of physical activity from active transport achieved by at least half the California population that would meet the U.S. Surgeon General's physical activity guidelines,[31] which for adults is 150 weekly minutes of moderate physical activity (USSG1.0). A fourth scenario would relax this level to 75 weekly minutes (USSG0.5).

These scenarios were aligned with ITHIM inputs as follows. For the CSMP2020, the goal was stated in terms of doubling/tripling the percentage of trips of non-car modes. Because ITHIM inputs are based on distances and travel time, per capita mean daily travel distances were doubled from 2010 baseline levels in each region for walking and transit and tripled for bicycling. Likewise, in AT2030, walking and transit were quadrupled from 2010 levels and increased 9-fold for bicycling. The population distribution of active travel time is highly skewed (log normal) with a significant proportion of the population with little or no walking and cycling. To implement the USSG scenarios, the goal was set using the population median rather than the mean level of active travel time.

The amount of increased walking, bicycling, and transit that replaces car miles influences per mile risk of road traffic injuries, air pollution, and carbon emissions. As a conservative assumption, each scenario assumed that each mile of increased active travel would replace only half as much car VMT. (In fact, active transport might displace car VMT more than mile-per-mile, as people biking and walking frequently choose closer destinations.) The replaced car miles were restricted to local roads and arterials where pedestrians and cyclists are present. In California there is a large reservoir of short car trips that can be replaced: 16% of all car trips are less than 1 mile, 32% are from 1 to 3 miles in length, and 16% are between 3 and 5 miles. Eighteen percent of car VMT is traveled in trips less than 5 miles.[27] The spreadsheet version of ITHIM does not couple scenario distances of individual travelers to a distribution of origins and destinations for which the propensity to walk, cycle and use transit are known. To examine the impacts of this assumption on road traffic injuries, a sensitivity analysis was carried out by varying the level of car mile substitution from 0% to 100%.

Time Horizon

The age-, sex-, and cause-specific population attributable fractions in each scenario were applied to the 2010 California burden of disease. Therefore, the framing of the analytic question was "If the changes in active transport could be immediately realized, what would the health impacts have been in 2010?" This was done to simplify the analysis and assess the health impacts independently of opposing trends in population and mortality dynamics likely to occur over the next two decades. These include a demographic shift to older age groups which will increase the burden of disease, and falling mortality rates of specific diseases and road traffic injuries due to improved public health and medical advances.[32] In related research,[33] sensitivity analyses compared the same scenario in populations with 2010 and 2040 age distributions and cause-specific mortality rates. The overall change in disease burden of disease was greater in 2040, but per capita changes in deaths and DALYs were similar. Therefore, for simplicity, results are presented only at the 2010 time horizon.

RESULTS

Travel Patterns of Baseline and Scenarios

Annual travel distances and weekly travel times of active modes are presented in Table 1 for the 2010 California baseline and the four scenarios. In ascending order of active transport miles, the scenarios were CSMP2020, USSG0.5, AT2030, and USSG1.0. The CSMP2020 had the most modest increases from baseline levels. The AT2030 and USSG scenarios envisioned 3.5 to 4.25-fold increases in walking and transit, but varied by levels of bicycling. The USSG1.0 scenario envisioned the largest increase in bicycle travel, whose overall travel time equaled that of walking to meet the US Surgeon General's goal for physical activity. Across all modes, total distance mode share for active travel including transit was 5% at baseline, 10% for CSMP2020, 17% for USSG0,5, 20% for AT2030, and 27% for USSG1.0 (Appendix Table A1). Travel duration for walking and bicycling ranged from a per capita weekly mean of 84.5 minutes (CSMP2020) to 277 minutes (USSG1.0). Total cycling duration was similar for AT2030 and USSG0.5, but AT2030 allocated approximately one-third more time to walking.

Health Outcomes

For the CSMP2020 scenario, increases in active travel were associated with 2,095 fewer annual deaths (Table 1, Figure 2). This reflects an annual decrease of 2,348 deaths from chronic diseases linked to physical inactivity, and an annual increase of 254 deaths due to road traffic injures (Appendix Table A2). While risk of road traffic injures decreased per mile traveled for each mode, the large increase in active travel was associated with an increased annual number of deaths for pedestrians, cyclists, and transit passengers, but a decreased annual number of deaths for car occupants (Appendix Table A4). The impact of road traffic injuries in the CSMP2020 scenario was stronger when considering the DALYs, whose ratio was 41% of chronic disease (8,520 / 20,764).

This pattern of health benefits from chronic disease reduction and harms from road traffic injuries was observed in the other three scenarios of active transport (Table 1, Figures 2-3). Differences in health benefits and harms between the scenarios reflected the overall magnitude of active travel and the mode split between walking and bicycling. The USSG1.0 had the largest net health benefits with annual reductions in 8,747 deaths and 183,425 DALYs. AT2030 and the USSG0.5 had comparable overall levels of active transport, but a greater walk:bicycle time-mode share in the AT2030 scenario was associated with greater chronic disease reduction and fewer road traffic injuries (Appendix Table A4).

In the CSMP2020 and AT2030 scenarios, the change in net health benefits of California regions, expressed on a population basis, tended to follow the absolute magnitude of increases in active transport from baseline (Appendix Table A3.) The largest gains were in regions with the highest initial (baseline) levels of active transport, because the scenarios simply applied multipliers to those baseline levels, and the Bay Area stands out in this regard. In the USSG scenarios, which set a maximum level of active transport time independently of baseline levels, the regions with the lowest baseline levels of active transport (e.g. San Joaquin Valley) tended to gain the most health benefit.

The monetized value of health outcomes through disease reduction were substantial and varied by method of monetization and scenario (Table 1, Figure 4, Appendix Table A5). Across scenarios, COI estimates ranged from $1 billion to $5.7 per year. Within scenarios, the VSL method generated roughly 10 times the annual monetized amounts compared to COI. VSL estimates ranged from $15.5 billion for CSMP2020 to $59.6 billion for USSG1.0.

Aggregate carbon emission decreased as the total active transport miles increased (Table 1, Figure 5, Appendix Table A6). Holding population and emissions factors constant at 2010 levels, active transport scenarios were associated with carbon reductions of 3% (CSMP2020) to 14% (USSG1.0).

DISCUSSION

In the United States, physical inactivity is estimated to account for 6% of all deaths and approximately 30% of the mortality of ischemic heart disease, diabetes, colon cancer, and breast cancer, 13% of cerebrovascular disease,[34] and 21% of Alzheimer's disease.[35] In California, approximately 23,000 deaths annually are attributable to physical inactivity for these causes. Even the most modest active transport scenario in this analysis (CSMP2020) would make significant progress in reducing this burden of chronic disease among Californians. Achieving any of these goals would constitute a major public health achievement on par with California's successful efforts at tobacco control.[36] Based on national estimates of costs of illness (scaled to California regions) and the value of a statistical life, the annual value of chronic disease reduction for each scenario was substantial and ranged in billions of dollars.

In each scenario, chronic disease reductions were accompanied by increases in the number of serious and fatal road traffic injuries, despite falling injury risks per mile traveled. Active transport modes experienced the increases in injuries and car occupants experienced decreases. The burden from road traffic injuries depended on the level of active travel and the amount active transport substituted for car travel. For each of the four scenarios, the level of substitution was fixed at 50%. However, in sensitivity analyses (Appendix Table A8), in which the level of substitution was varied from 0 to 100%, only at high levels of active transport and substitution are sufficient car miles replaced to achieve a net decrease in road traffic injuries (Appendix Table A8, Figures A1-A2). This emphasizes the importance of measures to improve road traffic safety of active travelers while encouraging mode switching from cars to active transportation.

Decreased greenhouse gas emissions from car VMT reductions were meaningful for each scenario, which ranged from 3% to 14% of 2010 baseline emissions.

It merits stating that most ambitious scenarios increased per capita mean weekly active travel to 278 minutes, which is similar to the average time burden of 272 minutes experienced by California commuters considering all modes in 2010.[37]

Strengths, Limitation and Assumptions

ITHIM incorporates definitive health outcomes of disease-specific deaths and DALYs based on the physical activity-response gradient of well-designed, longitudinal studies. The comparative risk assessment methodology using the Global Burden of Disease is also well-established in predictive health modeling. For road traffic injuries, the model accounts for “safety-in-numbers” (for which pedestrian and bicyclist mode share itself is a determinant of injury rates) and traffic speed and volume, approximated by roadway type.

Outside the Bay Area, there were no available modeled airborne concentrations of fine-particulate matter that took into account emissions (or VMT) from cars and stationary sources, meteorology, and air shed chemistry. Each scenario was run using available data for the Bay Area, and the results illustrate that health benefits of active travel from physical activity are orders of magnitude greater than those from reduction in $PM_{2.5}$ (Appendix Table A7). The overwhelming majority of health impact studies in the United States and Europe (with varying contributions of transportation to total air shed $PM_{2.5}$) report similar findings.[10] Additional studies demonstrate that, except for the most contaminated international air sheds, the health benefits of physical activity among active travelers, whose proximity to busy roadways and increased ventilation rates might increase pollution uptake, far exceeds potential harms from increased exposure to vehicular air pollution.[38] Thus, except perhaps in exceptional circumstances, active transport in California benefits both the residents of the entire air shed and active travelers.

For this study, analyses incorporated simplifying assumptions such as realizing active travel changes and health benefits in the same accounting year, which was the same as the baseline. This does not take into account that implementation of active transport infrastructure and programs occurs in future decades, during which the California population will age and experience lower age-specific mortality for injuries and chronic diseases.[32] In related research,[33] sensitivity analyses have been carried out in which population and mortality trends were modeled for scenarios at a specific future year (e.g. 2040). While the burden of disease was larger in the future due to population growth and a greater proportion of older persons, the change in the burden of disease expressed on a population basis (per 100,000 people), varied little whether the accounting year was 2010 or 2040. This observation supports the reasonableness of the current approach.

Conclusions and Recommendations

There are large health benefits associated with achieving California's mobility- and health-based active transport goals. Significant carbon mitigation may also be achieved if increases in active travel are accompanied by concomitant decreases in car travel. Active travel generates reductions in chronic disease, but the overall health benefit of active transportation is also benefitted by the control of road traffic injuries, which are substantially influenced by both active travel mode share and car VMT substitution.

ITHIM is a transportation and health modeling tool, which, in this study, was implemented as a spreadsheet using aggregate data. To produce refinements to the projections in this report and provide insights at project level geographies, future versions of ITHIM will have to account for disaggregated travel behaviors through simulated California populations and integration with activity-based travel demand and land use models. Refined projections of transportation-related changes in air shed levels of $PM_{2.5}$ and other pollutants for all California geographies will further allow ITHIM to model all significant health pathways.

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Table 1. Travel Patterns, Health Outcomes, and Carbon Emissions by Scenario

Item	Baseline	Scenario*			
		CSMP2020	AT2030	USSG0.5	USSG1.0
Travel Distances, per capita mean miles/year					
Walk	85	170	340	296	362
Bicycle	29	87	261	395	1,449
Transit	424	848	1,696	1,478	1,812
Physical activity, per capita mean (median) min./week					
Walk	36.9 (17)	73.7 (36)	147.4 (78)	113.0 (56)	138.3 (75)
Bike	3.6 (2)	10.8 (5)	32.4 (17)	37.7 (19)	138.3 (75)
Total	40.5 (19)	84.5 (41)	179.8 (95)	150.6 (75)	276.5 (150)
Annual Change in Burden of Disease and Injury					
Deaths		-2,095	-5,550	-4,379	-8,057
Chronic Disease		-2,348	-6,015	-4,979	-8,747
Road Traffic Injuries		254	465	602	690
Disability Adjusted Life Years		-30,124	-92,905	-67,301	-142,101
Chronic Disease		-43,591	-117,603	-100,966	-183,425
Road Traffic Injuries		13,469	24,699	33,666	41,323
Monetized Costs (in billion 2010 Dollars)					
Cost of illness		-1.0	-3.6	-2.4	-5.7
Value of a Statistical Life#		-15.5	-41.0	-32.4	-59.6
Car Carbon emissions, MMT/yr, 2010	101.7	98.6	92.0	94.3	87.2

* CSMP, CalTrans Strategic Management Plan; USSG, U.S. Surgeon General; AT, Active Transport
# VSL, $7.4 million
MMT, Million Metric Tons
Note: Totals may not add up due to rounding

Figure 1. Integrated Transport and Health Impact Model (ITHIM) Integrates Data on Health and Travel

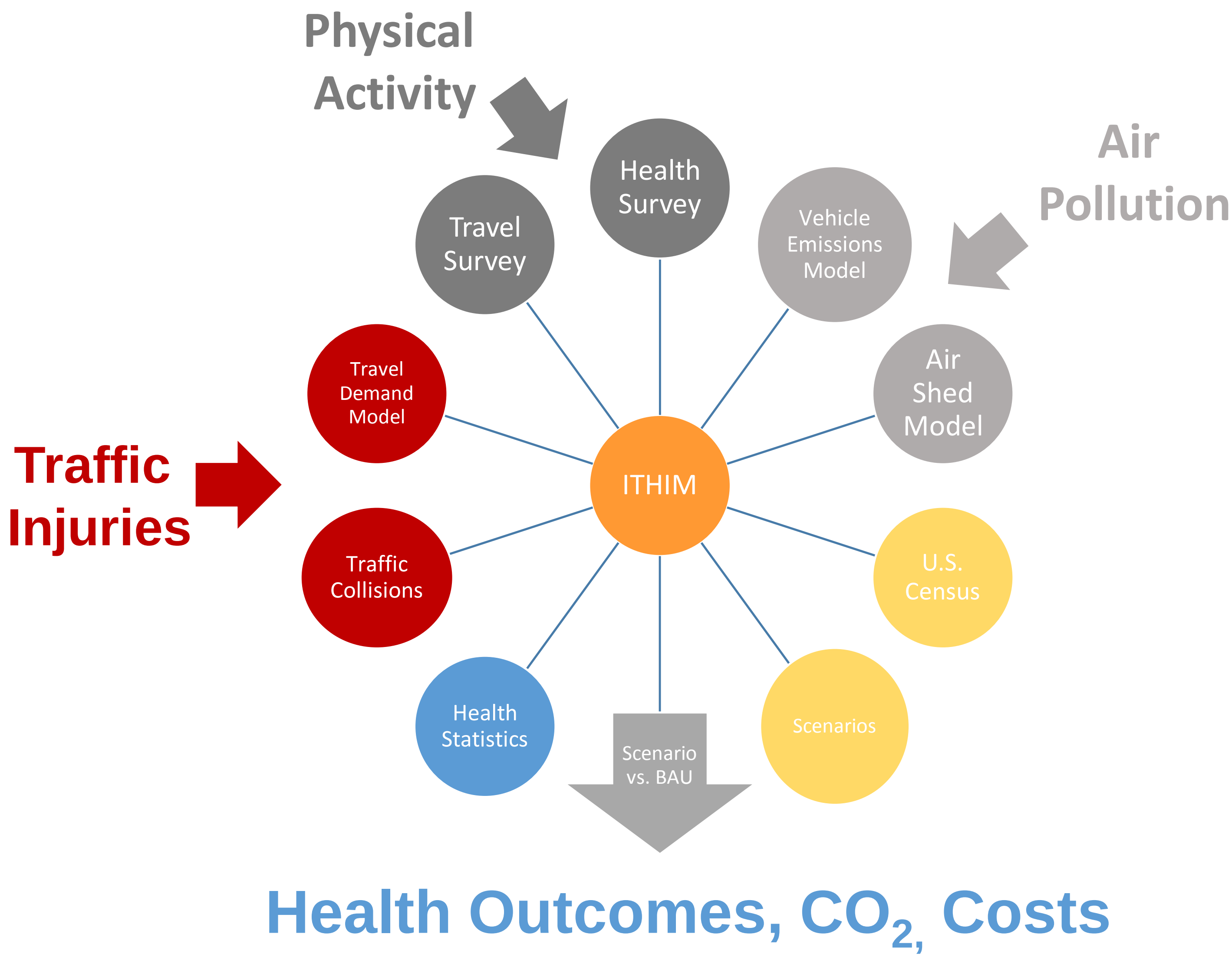


Figure 2.

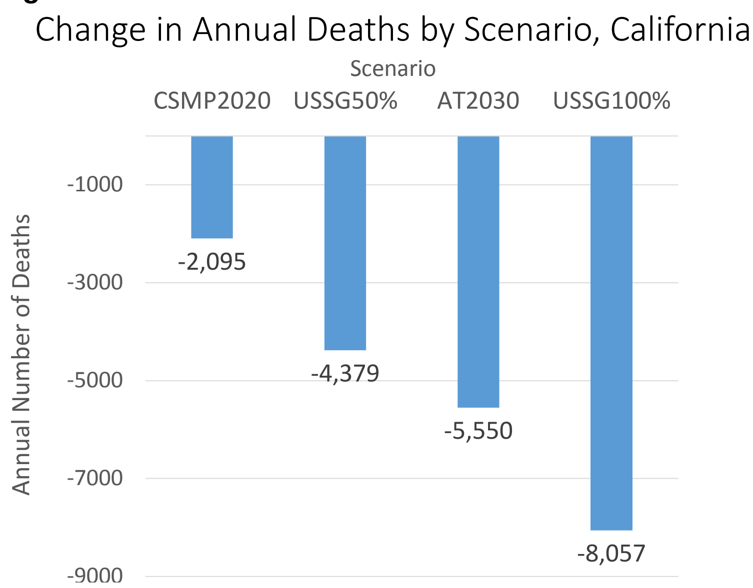
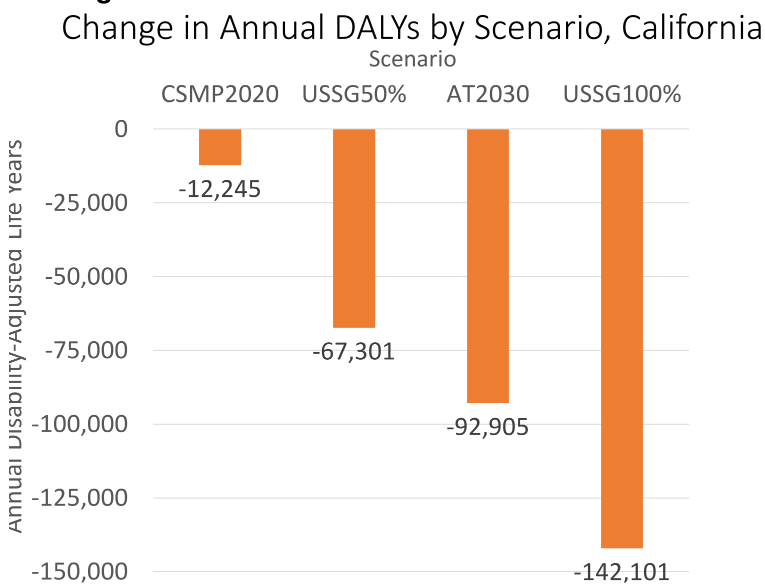


Figure 3.



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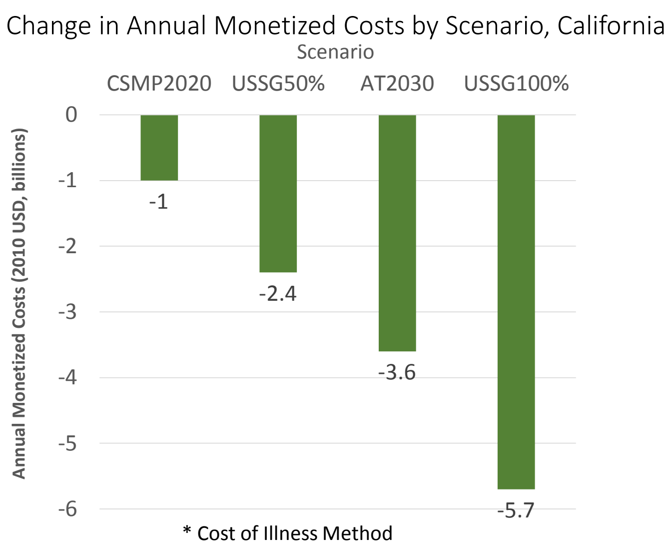

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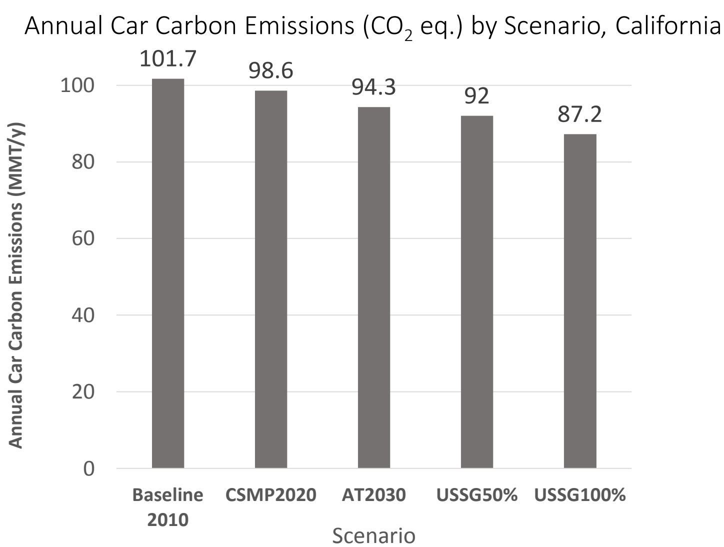

APPENDIX TABLES

Table A1. Per Capita Personal Travel Distance and Active Travel Times by Mode and Scenario, California

	Annual Distance (miles/person/yr)									Travel Time Mean (median) min./person/week		
			Car		Transit							
Scenario	Walk	Cycle	Driver	Pas-senger	Bus	Rail	Motor-cycle	Truck	Total	Walk	Cycle	Total
Baseline												
California, 2010	96	38	6,880	3,503	297	147	34	662	11,657	36.9 (17)	3.6 (2)	40.5 (19)
SF Bay Area*	151	61	5,683	1,824	294	354	48	677	9,093	57.8 (30)	5.9 (3)	63.7 (33)
San Joaquin Valley	73	18	6,207	3,257	398	8	23	1,108	11,092	27.8 (10)	1.8 (1)	29.6 (11)
Southern California	85	29	7,967	4,182	304	120	27	464	13,178	32.6 (15)	2.8 (1)	35.4 (16)
San Diego County	77	42	4,841	3,062	235	95	49	1,272	9,673	29.5 (15)	4.0 (2)	33.5 (17)
Sacramento Area	84	61	5,653	4,227	160	33	47	622	10,886	32.4 (15)	5.8 (2)	38.2 (17)
Scenarios#												
CSMP2020	192	113	6,671	3,405	594	293	34	662	11,964	73.7 (36)	10.8 (5)	84.5 (41)
AT2030	385	338	6,227	3,196	1,189	587	34	662	12,617	147.4 (78)	32.4 (17)	179.8 (95)
USSG0.5	295	393	6,384	3,250	999	390	34	662	12,406	113.0 (56)	37.7 (19)	150.6 (75)
USSG1.0	360	1,442	5,910	3,011	1,223	479	34	662	13,120	138.3 (75)	138.3 (75)	276.5 (150)

* San Francisco Bay Area counties: Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, Sonoma
Southern California counties: Imperial, Los Angeles, Orange, Riverside, San Bernardino, Ventura
San Joaquin Valley counties: Fresno, Kern, Kings, Madera, Modesto, Stanislaus, San Joaquin, Tulare
Sacramento Area counties: El Dorado, Placer, Sacramento, Sutter, Yolo, Yuba
CSMP, CalTrans Strategic Management Plan; USSG, U.S. Surgeon General
Note: Totals have been rounded

Table A2. Change in the Burden of Disease and Injury Due to Physical Activity and Road Traffic Injuries by Scenarios of Walking, Cycling and Transit, California

	Scenario							
	CSMP2020[†]				AT2030			
	ΔDeaths		ΔDALY[#]		ΔDeaths		ΔDALY	
Disease Category	PAF*, %	N	PAF, %	N	PAF, %	N	PAF, %	N
Cardiovascular disease	-2.7%	-1,583	-3.0%	-26,866	-7.1%	-4,212	-8.3%	-74,058
Diabetes	-2.7%	-190	-3.1%	-6,968	-7.2%	-515	-8.4%	-19,086
Dementia	-2.9%	-488	-2.6%	-5,489	-6.3%	-1,072	-5.9%	-12,322
Depression	0.0%	0	-0.8%	-2,801	0.0%	0	-2.3%	-8,161
Colon Cancer	-1.2%	-48	-0.9%	-709	-2.9%	-116	-2.5%	-1,897
Breast Cancer	-0.9%	-36	-0.7%	-718	-2.2%	-91	-1.9%	-1,951
Sum of Above		-2,345		-43,550		-6,006		-117,476
Road Traffic Injuries	7.8%	254	7.6%	13,469	14.3%	465	14.1%	24,699
Net[‡]		-2,091		-30,081		-5,541		-92,777

	US Surgeon General, 50%				US Surgeon General, 100%			
	ΔDeaths		ΔDALY		ΔDeaths		ΔDALY	
Disease Category	PAF, %	N	PAF, %	N	PAF, %	N	PAF, %	N
Cardiovascular disease	-5.9%	-3,532	-7.2%	-64,892	-10.7%	-6,376	-13.1%	-118,058
Diabetes	-6.1%	-436	-7.4%	-16,707	-11.1%	-789	-13.3%	-30,318
Dementia	-4.9%	-843	-4.7%	-9,730	-7.5%	-1,288	-7.4%	-15,450
Depression	0.0%	0	-1.8%	-6,537	0.0%	0	-3.8%	-13,694
Colon Cancer	-2.4%	-95	-2.1%	-1,557	-4.3%	-174	-4.2%	-3,190
Breast Cancer	-1.7%	-70	-1.4%	-1,500	-2.8%	-112	-2.5%	-2,618
Sum of Above		-4,976		-100,923		-8,739		-183,328
Road Traffic Injuries	18.5%	602	19.2%	33,666	21.2%	690	23.6%	41,323
Net[‡]		-4,374		-67,257		-8,049		-142,005

[†] CSMP, CalTrans Strategic Management Plan; USSG, U.S. Surgeon General; AT, Active Transport;* PAF, Population Attributable Fraction
[#] DALY, Disability Adjusted Life Year
‡ Totals have been rounded and exclude causes for air pollution-related deaths and DALYs (see Table A7 for Bay Area details)

Table A3. Change in Number and Rate (× 10^5 population) of Deaths and Disability Adjusted Life Years from Chronic Disease and Road Traffic Injuries by California Region, Scenarios of Walking, Cycling and Transit Compared to the 2010 Baseline

Change in Burden of Disease by Scenario	Bay Area		San Joaquin Valley		Southern California		San Diego		Sacramento Area		Total	
	ΔN	*ΔRate*	ΔN	*ΔRate*	ΔN	*ΔRate*	ΔN	*ΔRate*	ΔN	*ΔRate*	ΔN	*ΔRate*
CSMP2020												
Deaths, Total	-651	*-8.9*	-170	*-4.0*	-992	*-5.2*	-157	*-5.1*	-125	*-5.3*	-2,095	*-5.8*
Chronic Disease	-686	*-9.3*	-179	*-4.2*	-1,152	*-6.0*	-184	*-5.9*	-147	*-6.2*	-2,348	*-6.5*
Road Traffic Injuries	35	*0.5*	10	*0.2*	160	*0.8*	27	*0.9*	22	*0.9*	254	*0.7*
DALYs, Total	-10,922	*-148.6*	-2,385	*-56.5*	-12,245	*-63.8*	-2,352	*-76.0*	-2,220	*-93.4*	-30,124	*-83.1*
Chronic Disease	-12,862	*-175.0*	-2,934	*-69.5*	-20,764	*-108.1*	-3,717	*-120.1*	-3,314	*-139.4*	-43,591	*-120.2*
Road Traffic Injuries	1,940	*26.4*	549	*13.0*	8,520	*44.4*	1,365	*44.1*	1,095	*46.1*	13,469	*37.2*
AT2030												
Deaths, Total	-1,583	*-21.5*	-477	*-11.3*	-2,638	*-13.7*	-460	*-14.9*	-392	*-16.5*	-5,550	*-15.3*
Chronic Disease	-1,618	*-22.0*	-446	*-10.6*	-2,999	*-15.6*	-515	*-16.6*	-437	*-18.4*	-6,015	*-16.6*
Road Traffic Injuries	35	*0.5*	-31	*-0.7*	361	*1.9*	55	*1.8*	45	*1.9*	465	*1.3*
DALYs, Total	-28,963	*-394.0*	-11,071	*-262.1*	-38,602	*-201.0*	-7,159	*-231.3*	-7,110	*-299.0*	-92,905	*-256.3*
Chronic Disease	-31,099	*-423.0*	-9,194	*-217.7*	-57,907	*-301.5*	-10,013	*-323.5*	-9,390	*-394.9*	-117,603	*-324.4*
Road Traffic Injuries	2,136	*29.1*	-1,877	*-44.4*	19,305	*100.5*	2,855	*92.2*	2,280	*95.9*	24,699	*68.1*
USSG0.5												
Deaths, Total	-601	*-8.2*	-475	*-11.2*	-2,603	*-13.6*	-410	*-13.2*	-290	*-12.2*	-4,379	*-12.1*
Chronic Disease	-629	*-8.6*	-608	*-14.4*	-2,952	*-15.4*	-460	*-14.9*	-330	*-13.9*	-4,979	*-13.7*
Road Traffic Injuries	28	*0.4*	133	*3.1*	350	*1.8*	50	*1.6*	41	*1.7*	602	*1.7*
DALYs, Total	-11,115	*-151.2*	-5,526	*-130.8*	-38,755	*-201.8*	-6,503	*-210.1*	-5,402	*-227.2*	-67,301	*-185.6*
Chronic Disease	-12,936	*-176.0*	-13,650	*-323.2*	-57,825	*-301.1*	-9,116	*-294.5*	-7,439	*-312.9*	-100,966	*-278.5*
Road Traffic Injuries	1,821	*24.8*	8,124	*192.3*	19,071	*99.3*	2,613	*84.4*	2,037	*85.7*	33,666	*92.9*
USSG1.0												
Deaths, Total	-1,145	*-15.6*	-879	*-20.8*	-4,583	*-23.9*	-815	*-26.3*	-635	*-26.7*	-8,057	*-22.2*
Chronic Disease	-1,197	*-16.3*	-1,048	*-24.8*	-4,968	*-25.9*	-858	*-27.7*	-676	*-28.4*	-8,747	*-24.1*
Road Traffic Injuries	52	*0.7*	169	*4.0*	385	*2.0*	43	*1.4*	41	*1.7*	690	*1.9*
DALYs, Total	-23,922	*-325.4*	-13,182	*-312.1*	-78,737	*-410.0*	-14,336	*-463.2*	-11,924	*-501.5*	-142,101	*-392.0*
Chronic Disease	-27,703	*-376.9*	-23,807	*-563.6*	-100,824	*-525.0*	-16,962	*-548.0*	-14,129	*-594.3*	-183,425	*-506.0*
Road Traffic Injuries	3,780	*51.4*	10,624	*251.5*	22,088	*115.0*	2,626	*84.8*	2,205	*92.7*	41,323	*114.0*

Table A4. Annual Number and Rate* per Mile Traveled of Fatal and Serious Injuries by Mode and Scenario, California

Mode	Baseline		Scenario							
			CSMP2020		AT2030		USSG0.5		USSG1.0	
	N	Rate	N	Rate	N	Rate	N	Rate	N	Rate
Walk	2,409	6.91	3,335	4.78	4,403	3.16	4,115	3.85	4,110	3.15
Bicycle	905	6.65	1,557	3.81	2,598	2.12	2,967	2.08	5,512	1.05
Bus	34	0.03	56	0.03	97	0.02	87	0.02	103	0.02
Car	7,791	0.21	7,419	0.20	6,545	0.19	6,978	0.20	5,958	0.18

* Rate = Number of injuries per 10^7 mi. y^{-1} traveled by injured party (victim) of a road traffic collision

Table A5. Annual Monetized Value of Health Outcomes by Monetization Method and Scenario, California

Scenario	COI#	VSL†
CSMP2020	-$1,066,575,116	-$15,501,359,202
AT2030	-$3,566,007,374	-$41,070,545,040
USSG0.5	-$2,405,077,795	-$32,397,542,597
USSG1.0	-$5,675,118,580	-$59,618,402,889

* Constant 2010 dollars
# COI, Cost of Illness
† VSL, Value of a Statistical Life ($7.4 million)

Table A6. Annual Car Carbon Emissions and 2010 Emissions Factors by California Region

Region	2010 Car Emissions Factors, g CO_2/mile	Carbon Emissions (MMT/yr)*								
			Scenario (2010 population)				Scenario (2040 population)			
		Baseline 2010	CSMP 2020	AT 2030	USSG 0.5	USSG 1.0	CSMP 2020	AT 2030	USSG 0.5	USSG 1.0
California	–	101.7	98.6	92.0	94.3	87.2	135.3	126.3	129.5	119.9
San Francisco Bay Area	408	17.0	16.0	13.8	16.0	14.5	20.7	17.8	20.7	18.8
San Joaquin Valley	419	11.0	10.7	10.1	9.7	8.6	13.5	12.7	12.2	10.9
Southern California	429	61.8	60.4	57.3	57.7	54.0	84.4	80.1	80.6	75.4
San Diego County	428	6.4	6.2	5.8	5.9	5.4	8.5	7.9	8.1	7.4
Sacramento Area	410	5.4	5.3	5.0	5.1	4.8	8.2	7.8	7.9	7.4

* MMT, Million Metric Tons

Table A7. Change in Burden of Disease and Injury by Source of Benefit and Harm and Scenario, Bay Area

	CSMP2020[†]		AT2030		USSG0.5		USSG1.0	
Disease Category	ΔDeaths	ΔDALYs*	ΔDeaths	ΔDALYs	ΔDeaths	ΔDALYs	ΔDeaths	ΔDALYs
Cardiovascular dis. (PA)	-450	-7,688	-1,111	-18,539	-445	-8,025	-821	-16,709
Cardiovascular dis. ($PM_{2.5}$)	-2	-23	-6	-71	-2	-23	-4	-54
Diabetes	-58	-2,141	-142	-5,121	-58	-2,252	-117	-4,839
Dementia	-151	-1,647	-296	-3,453	-101	-1,203	-204	-2,495
Depression	0	-916	0	-2,680	0	-988	0	-2,533
Colon Cancer	-13	-204	-32	-575	-12	-217	-27	-553
Breast Cancer	-11	-226	-27	-604	-9	-210	-20	-478
Lung Cancer	-1	-11	-2	-35	-1	-11	-2	-27
Respiratory Dis.	0	-5	-1	-14	0	-5	-1	-11
Inflammatory Heart Dis.	0	-2	0	-6	0	-2	0	-5
Acute Resp. Inf.	0	0	0	0	0	0	0	0
Sum of Above	-686	-12,862	-1,618	-31,099	-629	-12,936	-1,192	-27,649
Road Traffic Injuries	35	1,940	35	2,136	28	1,821	52	3,780
Net	-651	-10,922	-1,577	-28,892	-599	-11,093	-1,140	-23,868
Physical Activity	-683	-12,821	-1,608	-30,973	-626	-12,895	-1,189	-27,607
Air-pollution	-3	-40	-9	-125	-3	-40	-7	-96
Road Traffic Injuries	35	1,940	35	2,136	28	1,821	52	3,780

[†] CSMP, CalTrans Strategic Management Plan; USSG, U.S. Surgeon General; AT, Active Transport; PA, Physical Activity
* DALY, Disability Adjusted Life Year
Note: Totals have been rounded

Table A8. Change in the Burden of Injury by Percent of Active Transport Miles Substituted by Car Miles, by Scenario and Region, California

Scenario	Miles Substi-tuted, %	SF Bay Area		San Joaquin Valley		Southern Cal.		San Diego County		Sacramento Area		California	
		Deaths	DALYs	Deaths	DALYs	Deaths	DALYs	Deaths	DALYs	Deaths	DALYs	Deaths	DALYs
CSMP 2020	0	68	3,687	60	3,588	196	10426	36	1816	30	1,488	389	21,005
	25	52	2,824	35	2,080	178	9476	31	1592	26	1,292	322	17,264
	50	35	1,940	10	549	160	8520	27	1365	22	1,095	254	13,468
	75	18	1,032	-16	-1,007	142	7557	22	1135	18	895	184	9,613
	100	0	97	-43	-2,592	124	6588	18	904	14	694	113	5,692
AT2030	0	174	9,504	152	9,084	361	19,305	89	4,585	76	3,793	852	46,271
	25	108	6,026	63	3,772	496	26,539	72	3,736	61	3,048	801	43,121
	50	35	2,136	-31	-1,877	429	22,965	55	2,855	45	2,280	534	28,359
	75	-53	-2,492	-133	-8,014	291	15,545	37	1,936	29	1,484	171	8,460
	100	-181	-9,266	-248	-14,959	218	11,673	18	971	13	656	-181	-10,925
USSG0.5	0	74	4,235	229	13,856	492	26,751	78	4,054	64	3,162	937	52,058
	25	51	3,049	182	11,030	422	22,961	64	3,345	52	2,606	772	42,990
	50	28	1,821	133	8,124	350	19,071	50	2,613	41	2,037	602	33,665
	75	4	542	84	5,125	275	15,066	35	1,857	29	1,453	427	24,043
	100	-21	-797	32	2,016	198	10,931	19	1,070	17	853	245	14,074
USSG1.0	0	163	9,704	358	22,057	805	44,876	119	6,526	102	5,229	1,547	88,393
	25	109	6,864	266	16,503	604	33,953	83	4,660	72	3,766	1,135	65,746
	50	52	3,780	169	10,624	385	22,088	43	2,626	41	2,205	690	41,324
	75	-13	333	65	4,302	140	8,789	-2	331	7	508	197	14,264
	100	-89	-3,750	-51	-2,677	-154	-7,121	-57	-2,461	-31	-1,394	-381	-17,403

† CSMP, CalTrans Strategic Management Plan; USSG, U.S. Surgeon General; AT, Active Transport
* DALY, Disability Adjusted Life Year

Figure A1.

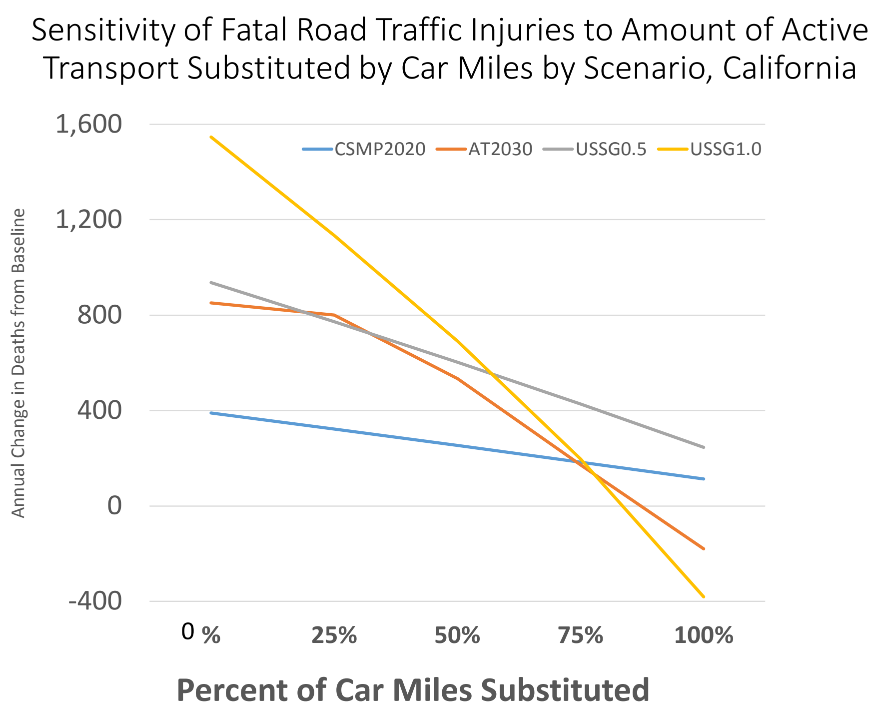

Figure A2.