Health Co-Benefits and Transportation-Related Reductions in Greenhouse Gas Emissions in the Bay Area

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Background

Green House Gas Emissions

- California's motorized transport sector accounts for 38% of greenhouse gas emissions, GHG (179 MMT CO_2E in 2003)
  - Personal passenger vehicles account for 30% (79% of 38%)
- Pathways to reduce GHG emissions is through vehicle miles traveled
  - Increased efficiency of fuel and vehicles
  - Reducing vehicle miles traveled (less trips, mode switching (SOV to mass transport), walking/bicycling (active transport)
    - Facilitated through policy, programs, and projects impacting the built environment (housing, transportation, food production, etc.)

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Background

Health Status

- Health status of a population is combined influence of biological and environmental factors whose pathways traverse individuals, families, neighborhoods, communities, regions, and nations – social determinants of health
- Public health meets urban planning: policies and practice that influence the built environment (housing, transportation, infrastructure, economy) are key determinants of population health (Sustainable Communities, HiAP, AB32/SB375)
- Strategies to reduce GHG emissions influence the built environment in a way that impacts population health
  - Do the strategies generate health co-benefits or harms?
  - What strategies yield significant health co-benefits?
  - How do we measure this?

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Aims and Objectives of the Integrated Transport & Health Impact Model (I-THIM) aka Woodcock Health Co-Benefits Model*

- To estimate the health impacts of alternative strategies for reducing carbon dioxide emissions from transport.
  - Lower carbon driving
    - Lower carbon emission motor vehicles/fuels
  - Increased active travel
    - Replacing urban car and motorcycle trips with walking or bicycling.

* Woodcock J, Edwards P, Tonne C, Armstrong BG, Ashiru O, Banister D, et al. Public health benefits of strategies to reduce greenhouse-gas emissions: urban land transport. The Lancet 2009;374:1930-1943.

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Co-Benefits of Active Transport, London

- Health impact pathways:
  - Physical Activity
  - Air Pollution
  - Road Traffic Injuries
- Scenarios of distances/times traveled by active transport instead of cars by 2030
  - Goal setting based on European cities with current high levels of walking/bicycling mode share:

Scenario	Mean mi./dy	Median min./dy	Mode Share
London Baseline, 2010	0.7	10.3	4%
Active Transport	2.2	30.4	19%

  - 50% of short trips distances by cars replaced with walking and bicycling
- Findings
  - ↓ 10-19% Cardiovascular Disease (3140-6820 deaths)
  - ↓ 12-13% Breast Cancer (200-210 deaths)
  - ↓ 7-8% Dementia (200-240 deaths)
  - ↑ 19-39% Road Traffic Injuries (50-80 deaths)
  - ↓ 38% in CO_2 emissions

Can Woodcock's Active Transport Model Be Reproduced for Regional Transportation Plans in California?

California Department of Public Health:

- Partner with MTC (regional MPO) and BAAQMD to apply the I-THIM Health Co-Benefits Model of Active Transport to the Bay Area
  - Test the feasibility
  - Develop a tool kit and technical resources to assist other MPOs apply the model to their geographic area

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Methods for Assessing Health Outcomes for Active Transport

- Comparative Risk Assessment
  - ✓ Δ Disease Burden = Attributable Fraction × Disease Burden

↓

Percent change in disease rates from BAU due to shift in exposure distribution in the alternative scenario

- $$AF = \frac{\sum_x RR_x \times \text{Population(BAU)}_x - \sum_x RR_x \times \text{Population(Alt.)}_x}{\sum_x RR_x \times \text{Population(BAU)}_x}$$

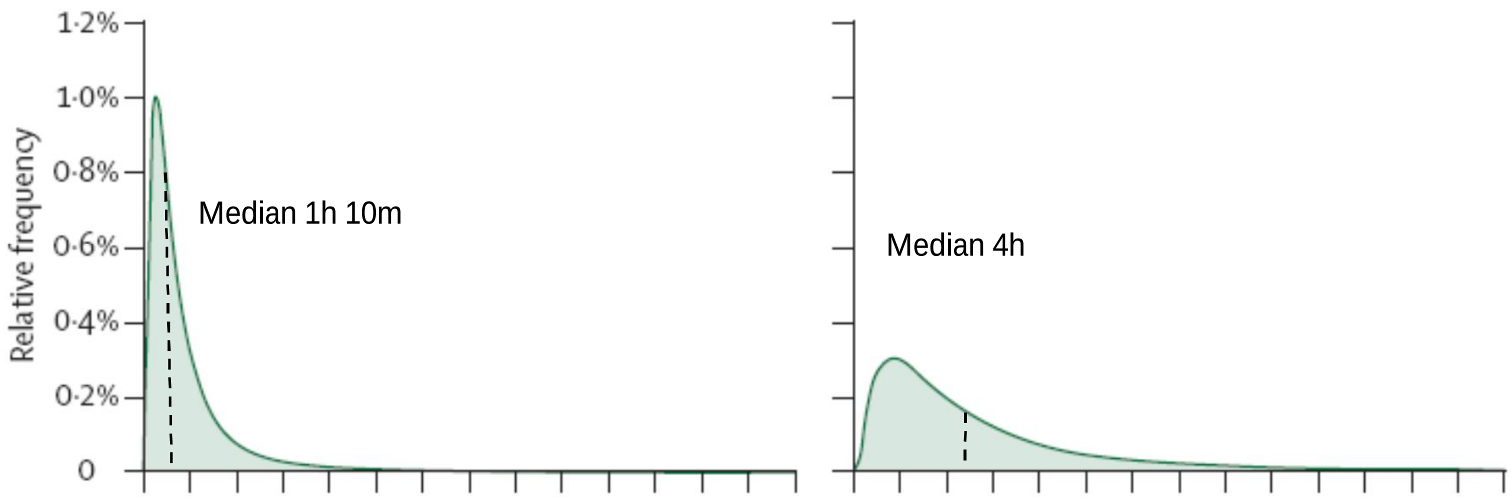
RR is the relative risk of the health outcome at the given exposure level

- For physical activity, exposure, *x*, is the hours per week spent in walking and bicycling (and all other physical activity),
- For air pollution, exposure, *x,* is the concentration of fine particulate matter ($PM_{2.5}$)
- Burden of Disease
  - ✓ Disability Adjusted Life Year, DALY, is a measure of premature mortality and disability based on the years of life lost, YLL (years of expected life - age at death) + years lived with a disability, YLD

DALY = YLL + YLD

Methods for Assessing Health Outcomes for Active Transport

- Modeling population distribution of weekly hours of physical activity



- Hours per week is converted to weekly MET hours based on age- and sex-specific walking and bicycling speeds (1 MET = 1 kcal/kg/hr)

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Health Outcomes

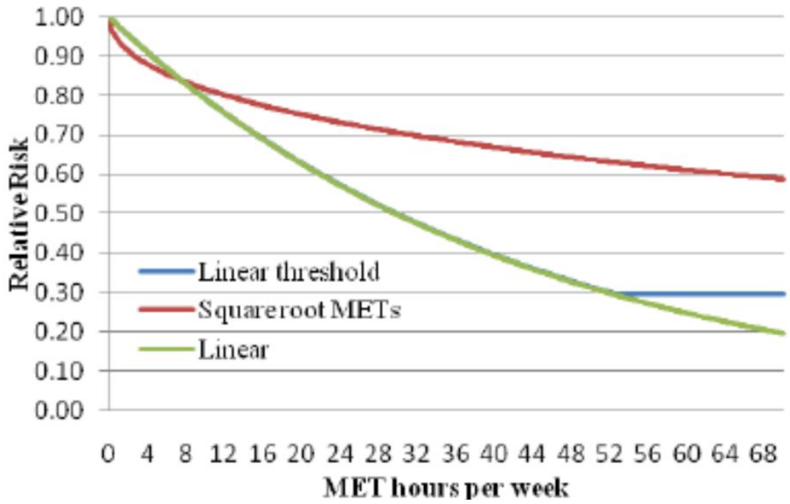
- Physical Activity
  - Based on strong quantitative evidence of a link between exposure pathways and health outcomes, the following health outcomes were chosen:

Condition	Studies included	Relative Risk	Exposure (Metabolic Equivalents)*
Breast cancer	19 cohort studies, 29 case control studies	0.94	each additional h/wk
Cardiovascular disease	18 cohort studies (459,833 people, 19,249 cases)	0.84	3 hrs walking per week (7.5 METs/wk)
Colon cancer	15 cohorts (7873 cases)	Women: 0.80	30.1 METs/wk
		Men: 0.86	30.9 METs/wk
Depression	Cohort study (10,201 men, 387 first episodes physician-diagnosed depression)		Kcal/wk
		1	<1000
		0.83	1000-2499
		0.72	2500+
Diabetes	10 cohort studies (301,211 people, 9367 cases)	0.83	10 METs/wk

* Metabolic Equivalent is amount of energy expended of a person at rest (1 MET = 1 kcal/kg/hr)

Health Outcomes

- RR come from literature review and some additional modeling of dose-response of physical activity



- Air pollution
  - ✓ Cardio-respiratory disease and lung cancer in adults
  - ✓ Acute respiratory infections (ARI) in children

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Health Outcomes

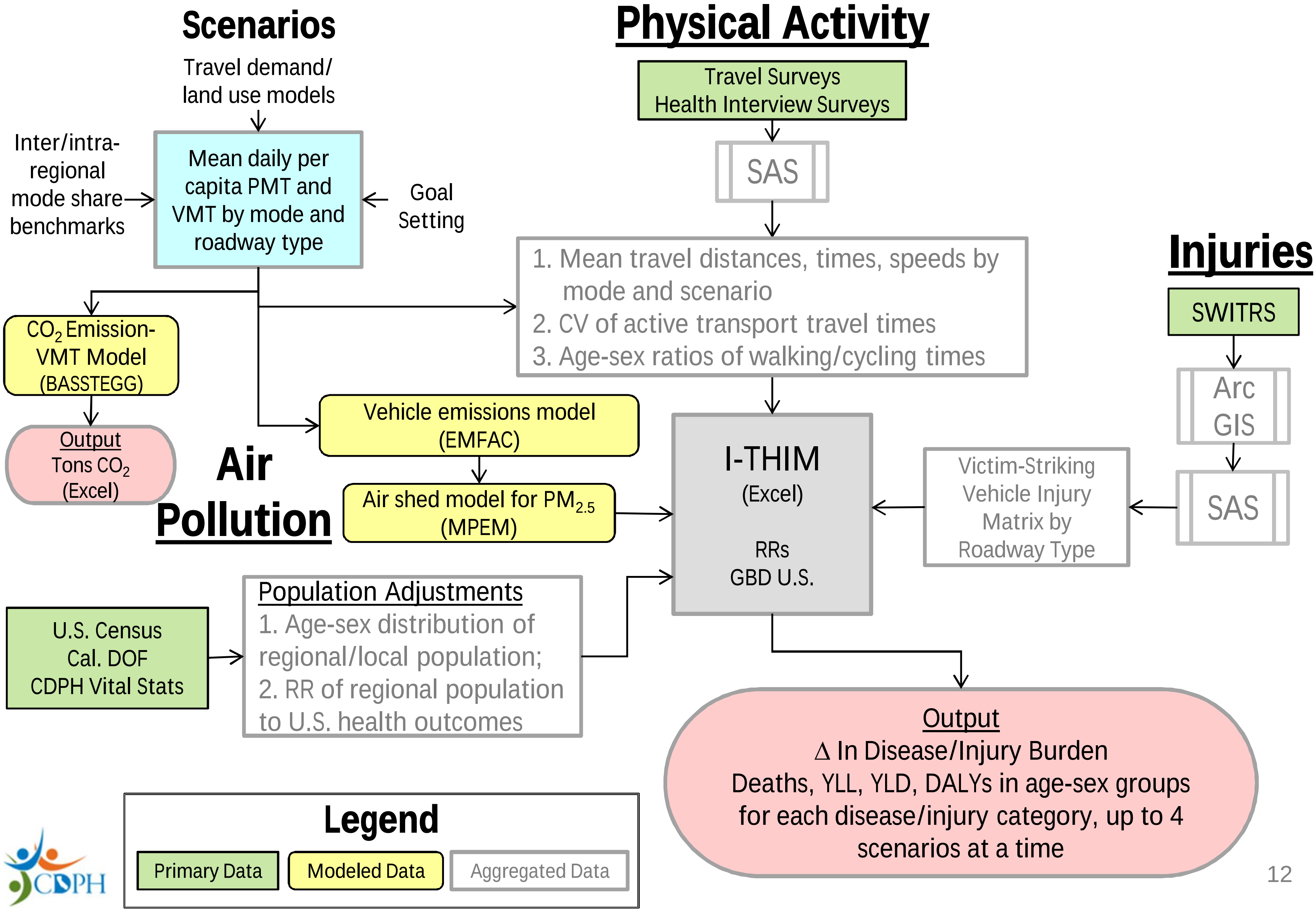
- Road Traffic Injuries: a mechanistic model based on injuries per miles traveled by the victim (PMT) and the striking vehicle (VMT)

Number of Injuries/Fatalities

Victim, V		Striking Vehicle, SV: b	p	m	c	d	h
Bicycle	b	r_{bb}	r_{bp}	r_{bm}	r_{bc}	r_{bd}	r_{bb}
Pedestrian	p	r_{pb}	r_{pp}	.	.	.	.
Motorcycle	m	r_{mb}	r_{mp}	r_{mm}	.	.	.
Car	c	r_{cb}	etc	.	.	.	.
Bus	d	r_{db}	.	.	.	.	.
Truck	h	r_{hb}	.	.	.	.	.

- Baseline Injury Risk: $R_0 = \dfrac{Injuries_{Victim0}}{PMT_{Victim0} \times VMT_{Striking\ Veh0}}$
- Scenario Injuries: $I_{S1} = R_0 \times PMT_{VictimS1} \times VMT_{StrikingVehS1}$
- Stratified by roadway type and severity (fatal, serious)

Structure of Model, Inputs & Outputs



Data Sources for Replicating Woodcock's Active Transport Model in California

Health Outcomes

- Global Burden of Disease database for U.S. (DALYs)
- SWITRS (traffic collisions)

Physical Activity

- Regional Travel Surveys (miles/minutes traveled by mode)
- California Health Interview Survey (non-transport related physical activity)

Carbon and Other Emissions

- Vehicle emissions (EMFAC) and air shed models for $PM_{2.5}$ (MPEM)
- CO_2 emissions per vehicle mile (MTC-BASSTEGG model)

Scenarios

- Output of travel demand and other models' scenarios
- Census/American Community Survey data on geographic variation of walking and bicycling rates
- Goal setting: health-based (minutes per week of physical activity) or GHG-based (percent reduction in CO_2 emissions from active transport)

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Active Transport Scenarios for the Bay Area

- What if whole Bay Area experiences the high levels of walking and cycling as the current leading Bay Area cities and/or US Cities (Portland, Seattle, Boston, etc.)?
  - Advantage of choosing local benchmarks
    - Familiarity and acceptability of the model's results by local policy makers.
    - The common elements of civil administration, regulations (general plan updates, mandates under SB375), and funding steams in the Bay Area
    - Strategies to achieve high level of active transport used by local standouts may be more transferable within California regions than those imported from outside the region or state.
    - Geography/topography
- Converting a percentage of the large number of short automobile trips to active transport
  - In 2006, 45% of Bay Area car trips were < 3 miles; 60% of car trips were < 5 miles
  - 50% of trips <1.5 miles walked and 50% of trips 1.5 to 5 miles bicycled
- How much would active transport have to substitute for vehicle miles traveled to meet the CO_2 reductions envisioned by AB32 and Executive Order S-3-05 (45% reduction from 2000 baseline by 2035) in combination with other strategies (Lutsey, 2010)?

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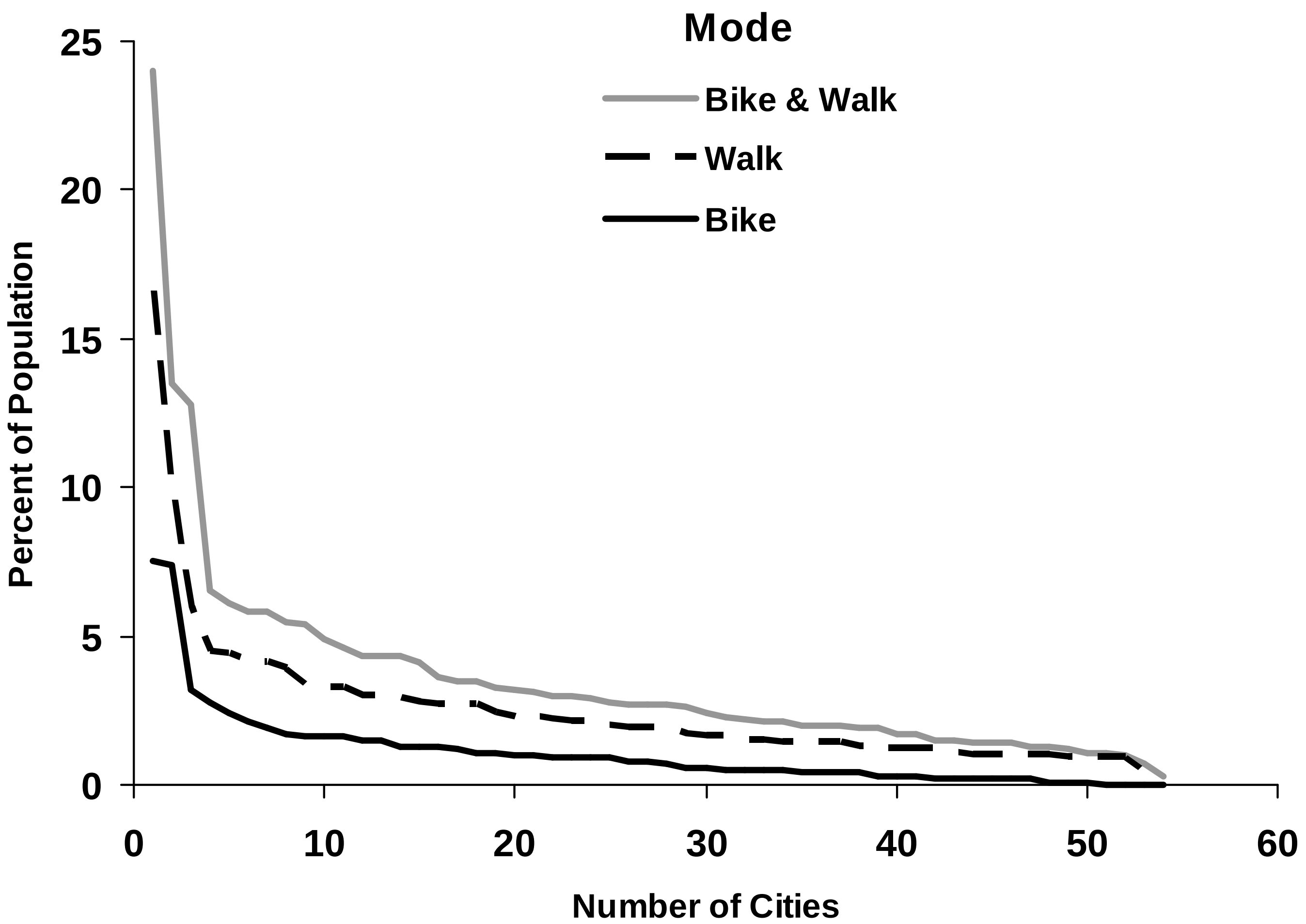
Percent of Working Population Aged ≥16 Years with a Journey to Work by Bicycle or Walking, 54 Bay Area Cities, 2007-2009



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The Top Decile of 53 Bay Area Cities Whose Working Population Commutes to Work by Walking or Bicycling

City	County	City population, 2007-9	Percent Commute 2007-9	Percent Commute 2035*
A. Bicycle to Work				
Palo Alto	Santa Clara	58,879	7.5	12.5
Berkeley	Alameda	101,426	7.4	11.8
Mountain View	Santa Clara	70,890	3.2	7.6
San Francisco	San Francisco	807,515	2.8	5.1
Rohnert Park	Sonoma	40,583	2.4	5.7
Midpoint of decile range			5.0	8.8
B. Walk to Work				
Berkeley	Alameda	101,426	16.6	21.2
San Francisco	San Francisco	807,515	10.0	11.8
Palo Alto	Santa Clara	58,879	6.0	16.0
Morgan Hill	Santa Clara	37,865	4.5	16.3
Oakland	Alameda	403,267	4.4	6.6
Midpoint of decile range			10.5	13.9

* Linear extrapolation of 2000-2009 annual growth rates of bicycling and walking
Source: American Community Survey, 3 year detailed tables, 2007-2009

- Linking ACS journey-to-work (JTW) to total miles traveled per scenario in travel survey data:

$$\text{Scenario Total Miles} = \text{Scenario JTW\%}_{ACS} \times \frac{\text{JTW Miles}_{BATS}}{\text{JTW Mode Share \%}_{BATS}} \times \frac{\text{Total Miles}_{BATS}}{\text{JTW Miles}_{BATS}}$$

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Scenarios for I-THIM Replication in the Bay Area

Scenario	Car*	Hvy Goods Vehicles	Bus	Rail	Bicycle	Walk	Total
Baseline, 2000	7,854	385	228	290	62	127	8,947
Business as Usual	8,247	385	228	290	62	127	9,339
Low Carbon Driving	8,247	385	228	290	62	127	9,339
Active Transport							
Top Decile$_{2009}$	7,921	385	228	290	274	241	9,339
Top Decile$_{2035}$	7,628	385	228	290	488	320	9,339
Short trips	7,631	385	228	290	575	230	9,339
Carbon Reduction Goal	7,036	385	228	290	1,000	400	9,339

* includes automobiles, light trucks, and motorcycles

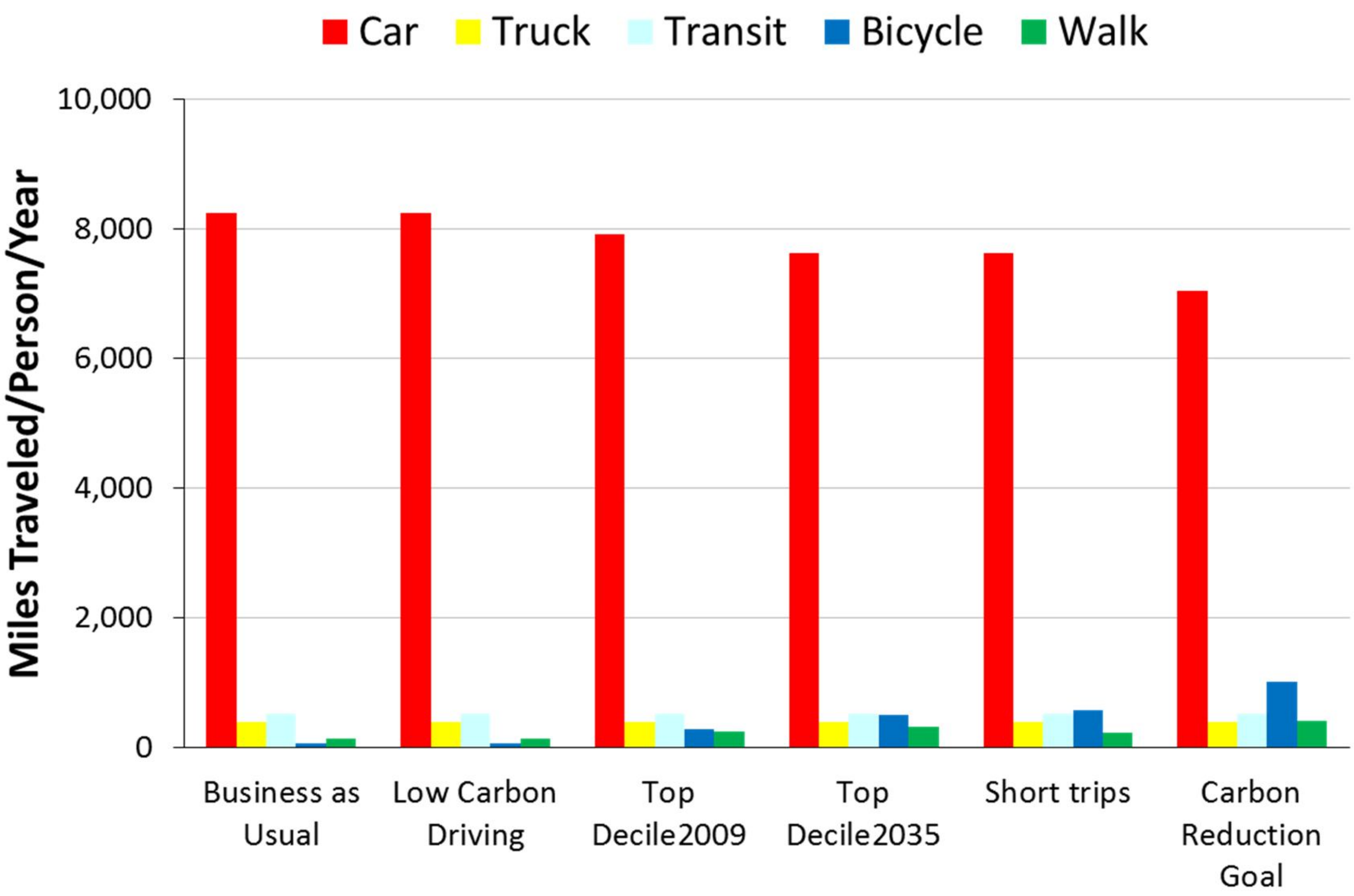
Low Carbon Driving:

- Penetration of gas-electric hybrid vehicles and light duty diesels, increased biofuels usage, and the penetration of electric vehicles (Pavley I&II) [See Lutsey, 2010]

Active Transport Scenarios

- 2-3 fold increase in walking (2.6%-4.3% of distance mode share)
- 4-16 fold increase in bicycling (2.9%-10.7% of distance mode share)
- Carbon reduction goal has 15% of distance mode share from active transport
- 4%-15% decrease in car VMT

Annual Per Capita Miles Traveled by Mode and Scenario



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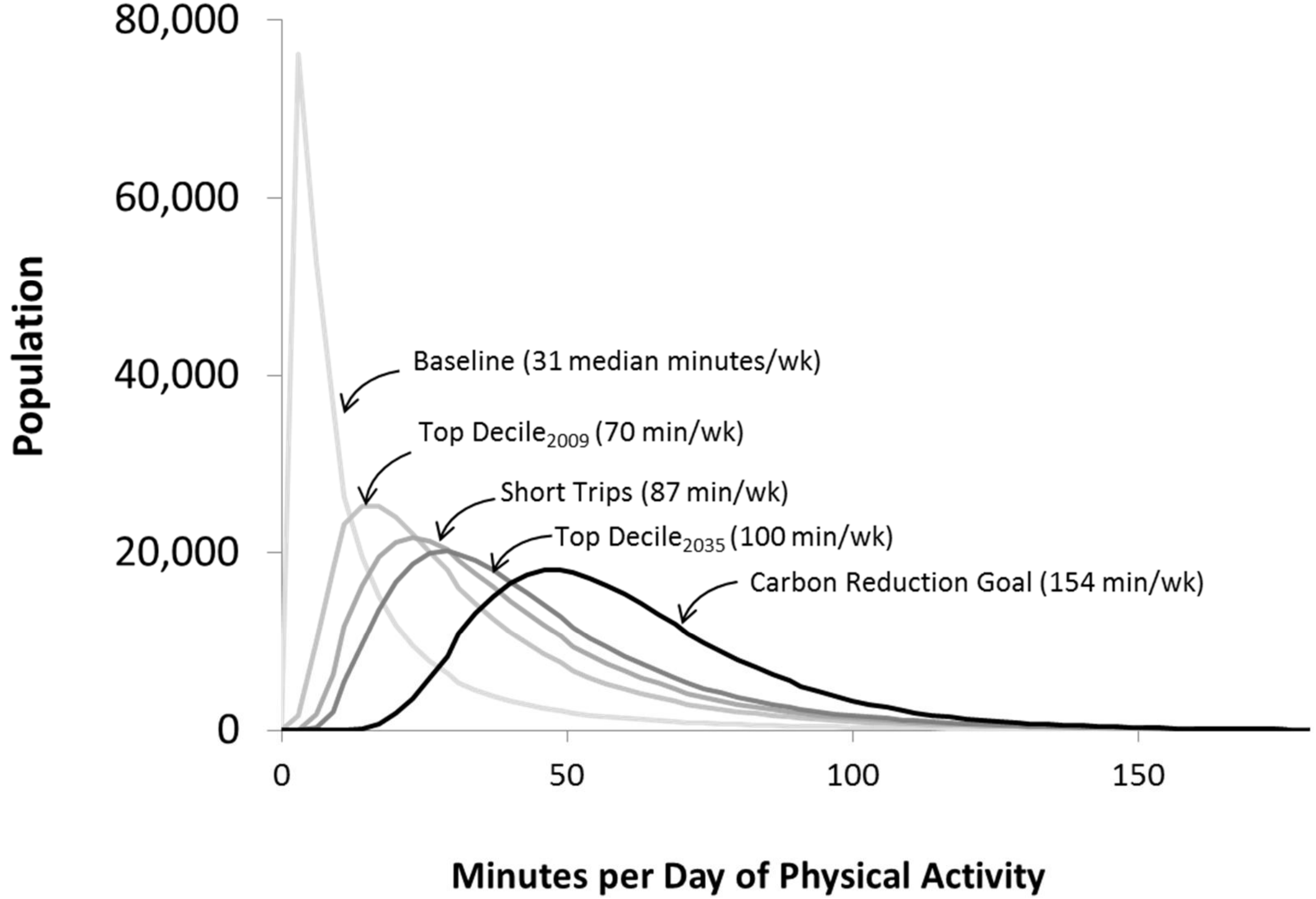
Physical Activity Distribution by Scenario



Health Impacts of Active Transport Scenarios

	Change in disease burden	Change in premature deaths
Cardiovascular Dis.	6-15% ↓	724-1895
Diabetes	6-15% ↓	73-189
Depression	2-6% ↓	<2
Dementia	2-6% ↓	38-132
Breast cancer	2-5% ↓	15-48
Colon Cancer	2-6% ↓	17-53
Road traffic crashes	19-39% ↑	60-113

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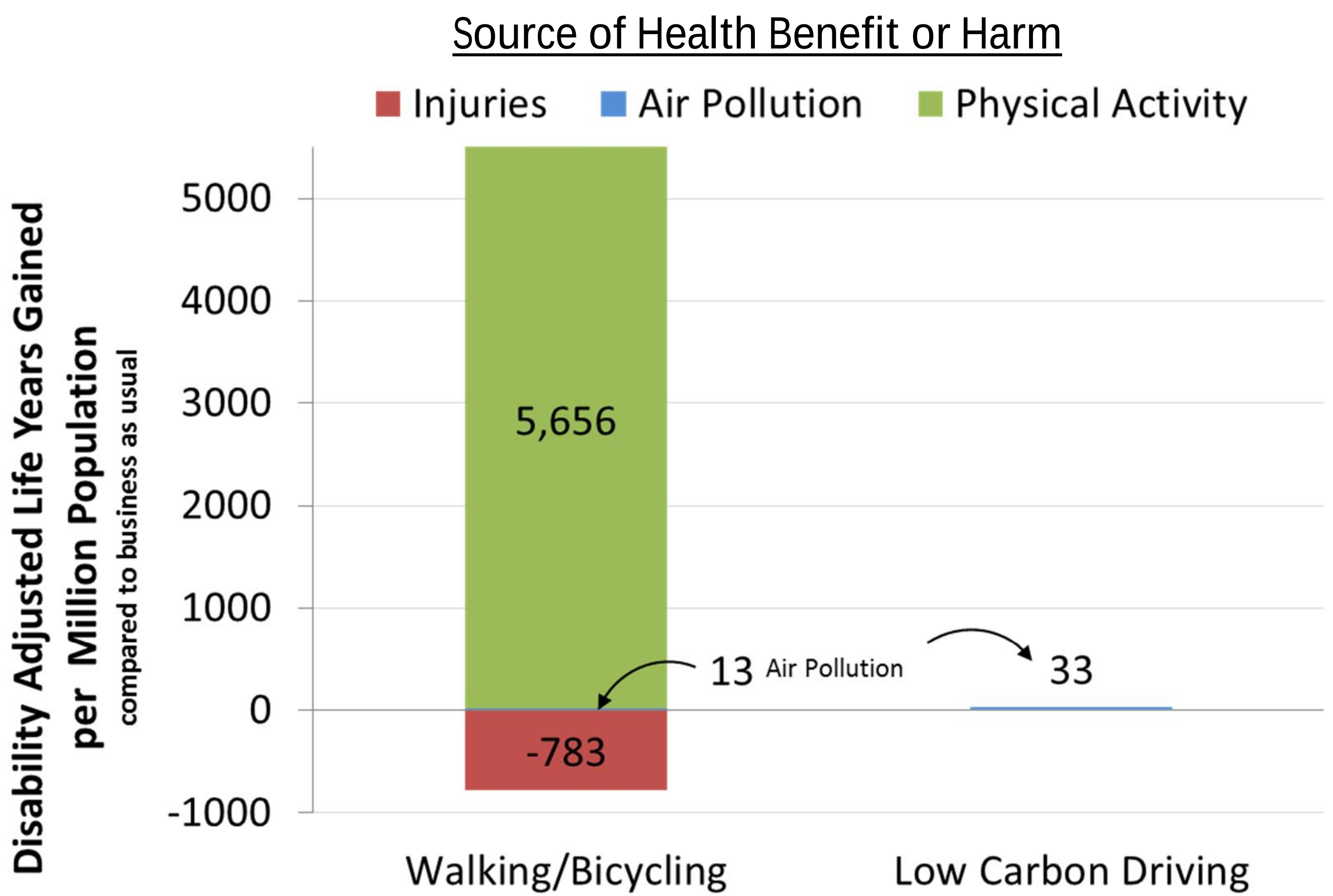
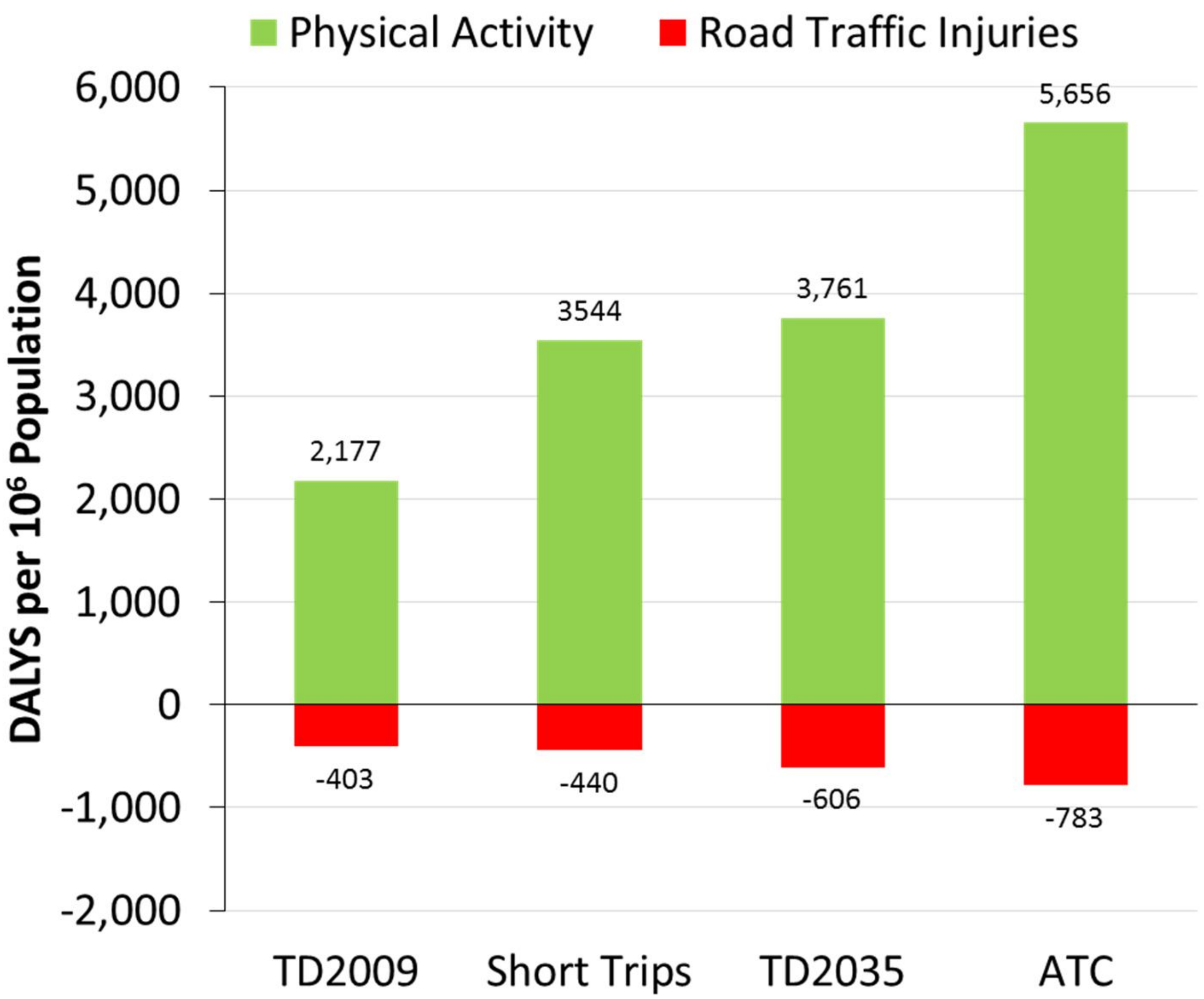
Annual Health Benefits of Active Transport and Low Carbon Driving in the Bay Area Predictions from the Woodcock Model

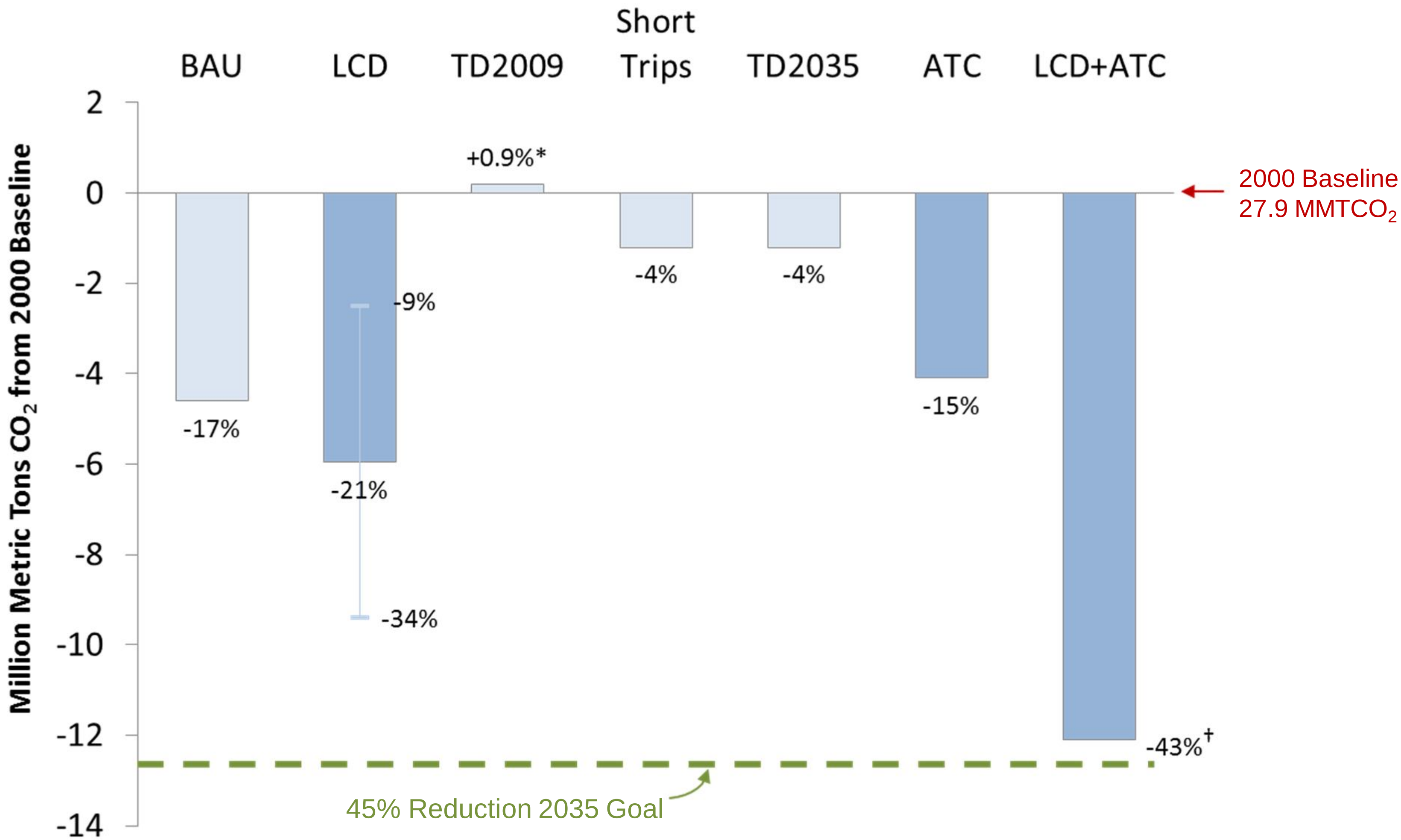


(Active transport
15% of miles traveled)

Health Impacts of Active Transport Scenarios



Annual Aggregate Reductions in Passenger Vehicle Greenhouse Gas Emissions from Different Transport Scenarios, San Francisco Bay#



Based on car VMT*BASSTEGG emission factor
* Per capita reduction of 26%
† Adjusted for double counting of mode choice
BAU, Business-as-Usual; LCD, Low Carbon Driving; TD, Top Decile of Cities; AT_C, Active Transport Carbon Goal

Summary of Findings

At 15% of all miles traveled by active transport

- Disease reductions
  - ↓ 14% of heart disease, stroke, and diabetes
  - ↓ 6-7% of dementia and depression
  - ↓ 5% of breast and colon cancer

  <u>Major public health impact; $34 billion annual health costs from CVD in California</u>
- Injuries
  - ↑ 19% of injuries to pedestrian and bicyclists
- Physical activity accounts for almost all the health benefits; air pollution < 1%
- ~15% reductions in CO_2 emissions
- Low carbon driving is not as important as physical activity for generating health co-benefits
- Together, low carbon driving and active transport can achieve California's carbon reduction goals and optimize the health of the population

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Strengths and Limitations

Strengths

- Evidence-based and population-based approach to quantify health co-benefits and harms
- Inputs are available from existing data from health and travel surveys, collision databases, and emissions and air shed models
- I-THIM could be a health co-benefits post-processor for travel and land use models that predict changes in modal distances (VMT)
- Runs on desktop computer in Excel (low cost/fast)

Limitations

- Simplifying assumptions
  - Co-benefits reported in a single accounting year
  - Secular trends in exposure (PA, RTI, $PM_{2.5}$) or disease rates not taken into account
- Other assumptions
  - Travel distances from BATS2000 travel surveys more accurate than travel times; reported walking and bicycling speeds in literature accurately reflect Bay Area walkers and bicyclists.
  - Road traffic injuries and travel distances follow asymptotic power function as reported in literature
  - CV of active travel time from 7-day CHIS survey adequately describes variability over 1 week
  - Scenarios fix miles traveled by transit, trucks, and rail; walking for transit not included (yet)
  - Less overall travel is an option
- Other issues: Won't health co-benefits be lost if walkers and bikers breathe polluted air next to busy traffic? Some studies show acute health effects, but on a population basis, co-benefits of physical activity far outweigh potential harms from increased exposure to polluted air (de Hartog, 2010)

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Next Steps

- Report back to community (LHDs, MTC Pedestrian/Bicycle Committee, other MPOs and stakeholders)
- Prepare toolkit to make I-THIM easier to use by MPOs and others interested in replicating model in their region
  - Preliminary workload projection to replicate I-THIM using CDPH templates and minimal technical assistance is 20-40 person days, depending on data contingencies and staff skill sets which could draw from several local agencies (e.g., health department, MPO, ACB, universities, etc.)
- Provide technical assistance to MPOs that are interested in exploring I-THIM
- Work with James Woodcock on model improvements

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Report available at:

http://www.cdph.ca.gov/programs/CCDPHP/Documents/ITHIM_Technical_Report11-21-11.pdf