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

Neil Maizlish, PhD, MPH, Epidemiologist

Califonia Department of Public Health
Center for Chronic Disease Prevention and Health Promotion

Presented at the Public Health Working Group of the Climate Action Team, Sacramento

November 28, 2011
Background

Transportation, food production, etc.

*Impacting the built environment (housing, etc.)*

Facilitated through policy, programs, and projects

*Transport* (SOV to mass transport, walking/bicycling, active transport)

Reducing vehicle miles traveled (less trips, mode switching) • Increased efficiency of fuel and vehicles • Reduced vehicle miles traveled

Pathways to Reduce GHG Emissions is Through Vehicle Miles Personal passenger vehicles account for 30% (79% of 38%)

Greenhouse gas emissions, GHG (179 MMT CO2 Eq in 2003)

California's motorized transport sector accounts for 38% of

Greenhouse Gas Emissions
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

Health Status

Background

Strategies to reduce GHG emissions influence the built environment in a way that impacts population health

HIA/P, AB32/SB375

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,

• public health round

• policies and practice that influence the built environment

• What strategies yield significant health co-benefits?

• Do the strategies generate health co-benefits or harms?

• How do we measure this?

What strategies yield significant health co-benefits?

Do the strategies generate health co-benefits or harms?

How do we measure this?
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 emissions from vehicles/fuels
- Lower carbon driving
- Increased active travel
- Replacing urban car and motorcycle trips with walking or bicycling.

Lower carbon driving

Co-Benefits of Active Transport, London

Health Impact Pathways:
- Physical Activity
- Air Pollution
- Road Traffic Injuries
- Physical Activity

Findings:
- 38% in CO₂ emissions
- 19-39% Road Traffic Injuries (50-80 deaths)
- 7-8% Dementia (200-240 deaths)
- 12-13% Breast Cancer (200-210 deaths)
- 10-19% Cardiovascular Disease (3140-6820 deaths)

Scenarios of distances/travelled by active transport instead of cars by 2030

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Mean mi./dy</th>
<th>Median mi./dy</th>
</tr>
</thead>
<tbody>
<tr>
<td>London Baseline, 2010</td>
<td>0.7</td>
<td>10.3</td>
</tr>
<tr>
<td>Active Transport</td>
<td>2.2</td>
<td>30.4</td>
</tr>
</tbody>
</table>

Goal setting based on European cities with current high levels of walking and bicycling:
- 50% of short trips 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 CO₂ emissions

Walking/Bicycling mode share:
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
### Methods for Assessing Health Outcomes for Active Transport

#### Assessing Health Outcomes

**Disease Burden**

- **Disability Adjusted Life Year (DALY)**: A measure of premature mortality and disability based on the years of life lost (YLL) and years lived with a disability (YLD), where:

\[
\text{DALY} = \text{YLL} + \text{YLD}
\]

- **Attributable Fraction (AF)**:
  
  \[
  \text{AF} = \frac{\text{RR} \times \text{Population(Alt.)}}{\text{RR} \times \text{Population(BAU)}}
  \]

- **Relative Risk (RR)**: The relative risk of the health outcome at the given exposure level.

- **For air pollution, exposure, χ, is the concentration of fine particulate matter (PM2.5)**

- **For physical activity, exposure, χ, is the number of hours per week spent in walking and bicycling (and all other physical activity)**

- **Percent change in disease rates due to shift in exposure distribution in the alternative scenario**

- **Comparative Risk Assessment**

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- **Comparative Risk Assessment**

- **Comparative Risk Assessment**
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)
Based on strong quantitative evidence of a link between exposure pathways and health outcomes, the following health outcomes were chosen:

**Physical Activity**

Health Outcomes

- **Breast cancer**: 19 cohort studies, 29 case control studies, 7.5 METs/wk (3 hrs walking per week). Relative Risk: 0.94 each additional h/wk.
- **Colon cancer**: 15 cohorts (7873 cases). Men: 30.9 METs/wk 0.86; Women: 30.1 METs/wk 0.80.
- **Diabetes**: 10 cohort studies (301,211 people, 9367 cases). Relative Risk: 0.83.
- **Depression**: 387 first episodes physician-diagnosed depression (10,201 men, Kcal/wk). Relative Risk: 0.83 for 1000-2499 Kcal/wk, 0.72 for 2500+ Kcal/wk.

Metabolic Equivalent is amount of energy expended by a person at rest (1 MET = 1 Kcal/hr).

* Metabolic Equivalent is amount of energy expended by a person at rest (1 MET = 1 Kcal/hr).
Health Outcomes

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

![Graph showing relative risk vs MET hours per week]

• Air pollution
  ✓ Cardio-respiratory disease and lung cancer in adults
  ✓ Acute respiratory infections (ARI) in children
Road Traffic Injuries: a mechanistic model based on injuries per miles traveled by the victim (PMT) and the striking vehicle (VMT) and the striking vehicle, SV. 

Stratified by roadway type and severity (fatal, serious) 

Baseline Injury Risk: $\mathcal{R}_0 = \frac{\text{Inj}}{\text{Victim}_0 \times \text{StrikingVeh}_0}$

Scenario Injuries: $\mathcal{S}_1 = \mathcal{R}_0 \times \frac{\text{PMT}_1 \times \text{Victim}_1 \times \text{StrikingVeh}_1}{\text{Inj} \times \text{Victim}_0 \times \text{StrikingVeh}_0}$

<table>
<thead>
<tr>
<th>Striking Vehicle, SV</th>
<th>Injuries</th>
<th>Victim, V</th>
<th>PMT</th>
<th>Striking Vehicle, SV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bicycle</td>
<td>m p m c</td>
<td>d p m c</td>
<td>q b</td>
<td>r p b q b m r m r m c</td>
</tr>
<tr>
<td>Pedestrian</td>
<td>m p m c</td>
<td>d p m c</td>
<td>q b</td>
<td>r p b q b m r m r m c</td>
</tr>
<tr>
<td>Motorcycle</td>
<td>m p m c</td>
<td>d p m c</td>
<td>q b</td>
<td>r p b q b m r m r m c</td>
</tr>
<tr>
<td>Car</td>
<td>m p m c</td>
<td>d p m c</td>
<td>q b</td>
<td>r p b q b m r m r m c</td>
</tr>
<tr>
<td>Bus</td>
<td>m p m c</td>
<td>d p m c</td>
<td>q b</td>
<td>r p b q b m r m r m c</td>
</tr>
</tbody>
</table>

Health Outcomes
Structure of Model, Inputs & Outputs

**Scenarios**
- Travel demand/land use models
  - Mean daily per capita PMT and VMT by mode and roadway type
  - Inter/intra-regional mode share benchmarks
- CO₂ Emission-VMT Model (BASSTEGG)
  - Output Tons CO₂ (Excel)
  - U.S. Census Cal. DOF CDPH Vital Stats

**Air Pollution**
- Vehicle emissions model (EMFAC)
  - Air shed model for PM₂.₅ (MPEM)
  - CO₂ Emission-VMT Model (BASSTEGG)
  - Output Tons CO₂ (Excel)

**Population Adjustments**
- 1. Age-sex distribution of regional/local population;
  - 2. RR of regional population to U.S. health outcomes

**Physical Activity**
- Travel Surveys
  - Health Interview Surveys
  - Sas
  - 1. Mean travel distances, times, speeds by mode and scenario
  - 2. CV of active transport travel times
  - 3. Age-sex ratios of walking/cycling times

**Injuries**
- SWITRS
  - Arc GIS
  - Sas

**Legend**
- Primary Data
- Modeled Data
- Aggregated Data

**Output**
- Δ In Disease/Injury Burden
  - Deaths, YLL, YLD, DALYs in age-sex groups for each disease/injury category, up to 4 scenarios at a time
Data Sources for Replicating Woodcock’s Active Transport Model in California

- Global Burden of Disease database for U.S. (DALYs)
- Global Burden of Disease database for California
- Census/American Community Survey data on geographic variation of walking and bicycling rates
- Output of travel demand and other models’ scenarios

Scenarios

- Vehicle emissions (EMFAC) and air shed models for PM2.5 (MPEM)
- CO2 emissions per vehicle mile (MMTC-BAStTGC model)
- Carbon and Other Emissions
- Vehicle emissions (non-transport related physical activity)
- California Health Interview Survey
- Regional Travel Surveys (miles/minutes traveled by mode)

Physical Activity

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

Health Outcomes

Goal Setting: health-based (minutes per week of physical activity) or GHG-based (percent reduction in CO2 emissions from active transport)
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.)?

How much would active transport have to substitute for vehicle miles traveled to meet the CO₂ reductions envisioned by AB32 and Executive Order S-3-05 (45%)?

- 50% of trips >1.5 miles walked and 50% of trips 1.5 to 5 miles bicycled
- In 2006, 45% of Bay Area car trips were >3 miles; 60% of car trips were >5 miles transport

Converting a percentage of the large number of short automobile trips to active transportation

- Geography/topography
- From outside the region or state, strategies to achieve high level of active transport used by local standouts may be more transferable within California regions than those imported.
- The common elements of civil administration, regulations (General Plan updates, mandates under SB375), and funding streams in the Bay Area: Familiarity and acceptability of the model’s results by local policy makers.
- Advantage of choosing local benchmarks.

(lutsey, 2010)
Percent of Working Population Aged ≥16 Years with a Journey to Work by Bicycle or Walking, 54 Bay Area Cities, 2007-2009
The Top Decile of 53 Bay Area Cities Whose Working Population Commutes to Work by Walking or Bicycling

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

* 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:

\[
\text{Scenario Total Miles} = \text{Scenario JTW\%}_{\text{ACS}} \times \frac{\text{JTW Miles}_{\text{BATS}}}{\text{JTW Mode Share \%}_{\text{BATS}}} \times \frac{\text{Total Miles}_{\text{BATS}}}{\text{JTW Miles}_{\text{BATS}}}
\]
### Scenarios for I-THIM Replication in the Bay Area

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Car*</th>
<th>Vans</th>
<th>Bicycles</th>
<th>Walk</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline, 2000</strong></td>
<td>7,854</td>
<td>385</td>
<td>228</td>
<td>290</td>
<td>62</td>
</tr>
<tr>
<td><strong>Business as Usual</strong></td>
<td>8,247</td>
<td>385</td>
<td>228</td>
<td>290</td>
<td>62</td>
</tr>
<tr>
<td><strong>Low Carbon Driving</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Penetration of gas-electric hybrids, and increased biofuels</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Active Transport Scenarios</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Top Decile 2009</strong></td>
<td>7,921</td>
<td>385</td>
<td>228</td>
<td>290</td>
<td>274</td>
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<tr>
<td><strong>Top Decile 2035</strong></td>
<td>7,628</td>
<td>385</td>
<td>228</td>
<td>290</td>
<td>488</td>
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<tr>
<td><strong>Low Carbon Driving</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Short trips</strong></td>
<td>7,036</td>
<td>385</td>
<td>228</td>
<td>290</td>
<td>1,000</td>
</tr>
<tr>
<td><strong>Carbon Reduction Goal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7.036</td>
<td>385</td>
<td>228</td>
<td>290</td>
<td>7.939</td>
</tr>
</tbody>
</table>

* Includes automobiles, light trucks, and motorcycles.

4%–15% decrease in car VMT

Carbon reduction goal has 1.5% of total distance mode share from active transport

4–16 fold increase in bicycling (2.9%–10.7% of distance mode share)

2–3 fold increase in walking (2.6%–4.3% of distance mode share)

Low Carbon Driving:

- Penetration of gas-electric hybrids and increased biofuels
- Increased use of electric vehicles (Pavley I&II) [See Lutsey, 2010]

Active Transport Scenarios

- Increased use of walking (2.6%–4.3% of distance mode share)
- Increased use of 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
Physical Activity Distribution by Scenario

- Baseline (31 median minutes/wk)
- Top Decile_{2009} (70 min/wk)
- Short Trips (87 min/wk)
- Top Decile_{2035} (100 min/wk)
- Carbon Reduction Goal (154 min/wk)
## Health Impacts of Active Transport Scenarios

<table>
<thead>
<tr>
<th></th>
<th>Change in disease burden</th>
<th>Change in premature deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cardiovascular Dis.</strong></td>
<td>6-15%</td>
<td>724-1895</td>
</tr>
<tr>
<td><strong>Diabetes</strong></td>
<td>6-15%</td>
<td>73-189</td>
</tr>
<tr>
<td><strong>Depression</strong></td>
<td>2-6%</td>
<td>&lt;2</td>
</tr>
<tr>
<td><strong>Dementia</strong></td>
<td>2-6%</td>
<td>38-132</td>
</tr>
<tr>
<td><strong>Breast cancer</strong></td>
<td>2-5%</td>
<td>15-48</td>
</tr>
<tr>
<td><strong>Colon Cancer</strong></td>
<td>2-6%</td>
<td>17-53</td>
</tr>
<tr>
<td><strong>Road traffic crashes</strong></td>
<td>19-39%</td>
<td>60-113</td>
</tr>
</tbody>
</table>
Annual Health Benefits of Active Transport and Low Carbon Driving in the Bay Area Predictions from the Woodcock Model

Source of Health Benefit or Harm

- Injuries
- Air Pollution
- Physical Activity

Disability Adjusted Life Years Gained per Million Population compared to business as usual

Walking/Bicycling:
- 5,656 (Green bar)
- -783 (Red bar)

Low Carbon Driving:
- 13 (Air Pollution)
- 33

(Active transport 15% of miles traveled)
Health Impacts of Active Transport Scenarios

- Physical Activity
- Road Traffic Injuries

<table>
<thead>
<tr>
<th>Scenario</th>
<th>DALYS per 10^6 Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>TD2009</td>
<td>-403</td>
</tr>
<tr>
<td>Short Trips</td>
<td>3544</td>
</tr>
<tr>
<td>TD2035</td>
<td>-606</td>
</tr>
<tr>
<td>ATC</td>
<td>-783</td>
</tr>
</tbody>
</table>

DALYS: Disability Adjusted Life Years
Annual Aggregate Reductions in Passenger Vehicle Greenhouse Gas Emissions from Different Transport Scenarios, San Francisco Bay#

-17%  -9%  +0.9%  -9%  -4%  -4%  -15%  -43%

2000 Baseline 27.9 MMTCO₂

45% Reduction 2035 Goal

Million Metric Tons CO₂ from 2000 Baseline

BAU  LCD  TD2009  Short Trips  TD2035  ATC  LCD+ATC

-14  -12  -10  -8  -6  -4  -2  0  2

# 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; ATC, Active Transport Carbon Goal
Summary of Findings

Carbon reduction goals and optimize the health of the population

Together, low carbon driving and active transport can achieve California’s health co-benefits

- Low carbon driving is not as important as physical activity for generating health benefits.
- Physical activity accounts for almost all the health benefits; air pollution < 1%
- Major public health impacts: $34 billion annual health costs from CVD in California
- 5% of breast and colon cancer
- 6-7% of dementia and depression
- 14% of heart disease, stroke, and diabetes
- At 15% of all miles traveled by active transport

Injuries
- 19% of injuries to pedestrians and bicyclists

Disease reductions
- ~15% reductions in CO2 emissions
- 1%


Injuries
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 emissions and air shed models
- Runs on desktop computer in Excel (low cost/fast)

**Limitations**

- Simplifying assumptions
  - Seemingly trends in exposure (PA, RTI, PM2.5) or disease rates not taken into account
  - Co-benefits reported in a single accounting year

- Other assumptions
  - CV of active travel time from 7-day CHIS survey adequately describes variability over 1 week
  - Travel distances from BAT2000 travel surveys more accurate than travel times; reported in literature

- 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)

- Scenario fixes miles traveled by transit, trucks, and rail; walking for transit not included (yet)
- Secular trend in exposure (PA, RTI, PM2.5) or disease rates not taken into account
Next Steps

- Report back to community (LHDs, MTC Pedestrian/Bicycle Committee, other MPoS)

- 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 replicating model improvements

- Work with James Woodcock on model improvements
Acknowledgements

The Team

Linda Rudolph, CDPH (conceived the project), Sacramento
Neil Maizlish, CDPH, Richmond
James Woodcock, UKCRC Centre for Diet and Activity Research (CEDAR), UK
Amir Farni and David Fairley, Bay Area Air Quality Management District, San Francisco
Bart Ostro, Centre for Research in Environmental Epidemiology (CREAL), Spain
Sean Co, Metropolitan Transportation Commission, Oakland
Linda Rudolph, CDPH (conceived the project), Sacramento

Partial Funding and Grant Support

Public Health Institute, Oakland
Public Health Law and Policy, Oakland, CA
Kaiser Permanente – Northern California Community Benefits Programs, Oakland
The California Endowment, Oakland

Other Contributors

Other Staff from MTC, UC Davis, CDPH, Mike Zdeb (University at Albany, NY)
Colin Mathers, World Health Organization, Geneva
Dr. Phil Edwards and Dr. Zaid Chalabi, London School of Hygiene and Tropical Medicine
Caroline Rodier, Urban Land Use & Transportation Program, UC Davis

Partially funded from MTC, UC Davis, CDPH, Mike Zdeb (University at Albany, NY)
Bibliography


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Contact Information

Neil Maizlish (Neil.Maizlish@cdph.ca.gov)

Report available at: