ITHIM CALIFORNIA | Integrated Transport and Health Impact Model

User's Guide and Technical Manual

California R/Shiny Version

by

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CALIFORNIA AIR RESOURCES BOARD

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Glossary of Acronyms and Terms

Acronym	Definition
BAU	Business as Usual
BD	Burden of Disease (includes injury)
CHIS	California Health Interview Survey
CHTS	California Household Travel Survey
CRA	Comparative Risk Assessment
CV	Coefficient of variation (standard deviation/mean)
CVD	Cardiovascular Disease
HHD	Hypertensive heart disease
DALY	Disability Adjusted Life Year = Years of Life Lost + Years Living with Disability
EMFAC	EMission FACtors model
Facility	Engineers' parlance for a roadway, bridge, highway ramp
GBD	Global Burden of Disease (includes injury)
ICD	International Classification of Diseases (5-digit hierarchical code)
ITHIM	Integrated Travel and Health Impact Model
MPO	Metropolitan Planning Organization
NHTS	National Household Transportation Survey
PA	Physical Activity
PAF	Population Attributable Fraction
PM2.5	Particulate matter with an aerodynamic diameter of 2.5 microns or less
PMT	Personal Miles Traveled (VMT and PMT are related through occupancy)
RR	Relative Risk (ratio of disease/injury rate in population with exposure over rate of disease/injury in a non-exposed population
RTI	Road Traffic Injuries
SWITRS	Statewide Integrated Traffic Records System
VMT	Vehicle Miles Traveled
WHO	World Health Organization
YLD	Years Living with Disability
YLL	Years of Life Lost

Introduction

The Integrated Transport and Health Impact Model (ITHIM) is a tool to quantify the health co-benefits of travel-related reductions in greenhouse gas emissions. Health impacts of active transportation and low carbon driving are mediated through changes in population distributions of physical activity, ambient fine particulate matter, and road traffic injuries. Use cases of ITHIM include:

- Quantify health benefits and harms of regional and local transportation and land use plans
- Provide information to policy makers on opportunities to improve the health impacts of their transportation investments
- Evaluate the health impacts of targets and project performance of regional transportation plans
- Provide a tool for students and researchers to learn about the interrelationships between health, transportation, and land use.

ITHIM has been implemented as a suite of related models in the United States and the United Kingdom that differ in platforms and capabilities. The development of ITHIM in the United States has been a partnership of regional transportation and state and federal health agencies in California, Oregon, Maryland, and Tennessee.

Purpose and Audience of this Guide

The purpose of this guide is to support users of the web-based California R/Shiny version of ITHIM (https://ww2.arb.ca.gov/ITHIM). While the *Guide* uses California data to illustrate use, calibration, and integration with travel demand models, the process may be adapted to other locations in the United States and other countries.

This guide is oriented to technical staff of governmental and nongovernmental organizations and academic researchers who want a detailed understanding of comparative risk assessment models, their data, and their implementation in California ITHIM. The *Guide* will help build a common vocabulary for technical staff from different disciplines – transportation and urban planning, epidemiology, health policy, economics – whose collaboration is an essential ingredient of a successful implementation.

For policy-oriented and less technical users, the California ITHIM website (https://ww2.arb.ca.gov/ITHIM) offers short video tutorials on website contents and navigation, and workshop slides that describe the health outcomes and mechanics of the model.

Organization of the Guide

The *Users' Guide* has two chapters and 3 technical appendices. Chapter 1 describes comparative risk assessment methodology, which is the conceptual and technical basis of the California ITHIM

model. It also describes the health outcome of disability adjusted life years. Chapter 2 reviews the features of the California ITHIM website. It describes each web page, how to navigate the website, and how to use the tool page (RunITHIM) to carry out a health impact analysis. This chapter also describes the scenarios that are pre-established (based on agency goals and plans) and "What if" scenarios that allow you to create scenarios on-the-fly by altering levels of walking, cycling, and transit. Appendix A describes how data were processed from primary sources to create calibration data. Appendix B describes the procedures to process and format outputs of travel demand or activity-based models as inputs for California ITHIM as user-uploaded scenarios. Appendix C describes how to user the application in developer's mode to carry out health impact analyses for different race/ethnicity groups.

Software History and Versions

ITHIM was originally developed by a research team headed by Dr. James Woodcock at London School of Hygiene and Tropical Medicine in 2010 and later at the University of Cambridge, United Kingdom. The first California version of ITHIM model was implemented as a spreadsheet in Excel using aggregate data for individual regions of California. Adaptations of this software for the United States and California have been co-developed by Dr. Neil Maizlish, affiliated with the California Department of Public Health (2011-2015), and the University of California, Davis (2018-2019). Dr. Woodcock has developed a version (2.5) based on aggregate data using the modeling software called Analytica. Dr. Woodcock's research team is developing R/Shiny versions of ITHIM (3.0) that simulate individuals' travel patterns and health outcomes in populations.

This release of California ITHIM (R/Shiny) represents a significant advance from previous spreadsheet versions (See comparison table next page).

Licensing

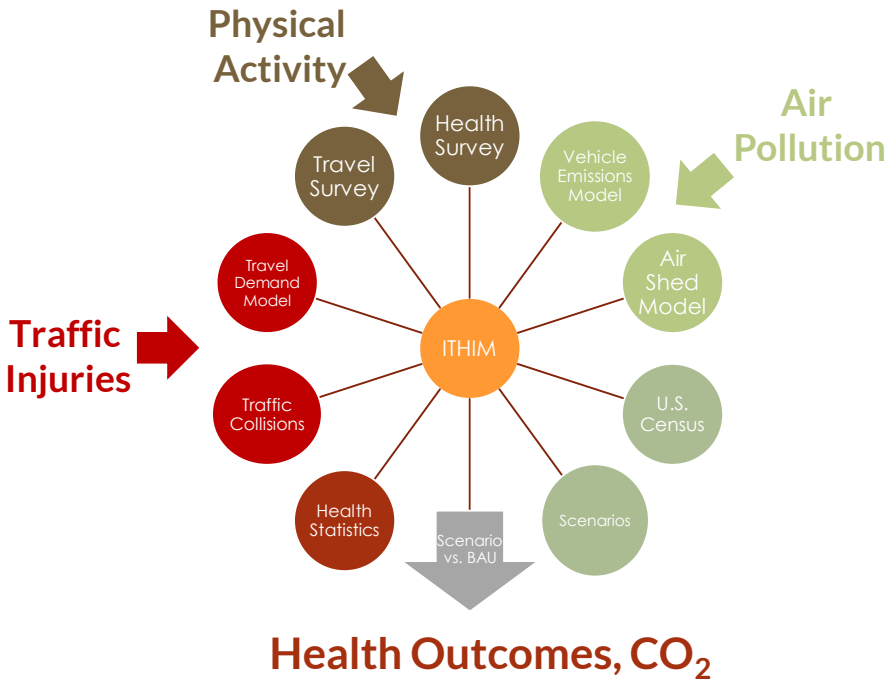
Comparison of Features in the Spreadsheet and R/Shiny Versions of California ITHIM

Feature	California ITHIM Version	
	Spread Sheet	R/Shiny
Years in Use	2011-2017	2019-
Analytic Engine	Five regional Excel workbooks with 35 Excel worksheets per workbook; formulae and data distributed in thousands of cells	One R program accessing 25 data files for California, regions, and counties
Interface	Rudimentary and difficult to use without training	R/Shiny web-application; easy to use and graphically appealing; tool driven by dropdown menus/radio buttons; background information and decision support materials incorporated into the website
Reporting	Highly detailed outputs distributed in multiple worksheets, specific for each region; statewide analysis require manual pooling of regional results	Outputs include a "mini report"/elevator pitch, infographic, publication-ready tables and graphs at summary, medium, and high level of detail; outputs available at user-selected geography (statewide, regional, county)
Scenarios	Regions varied in available scenarios	Travel data standardized for scenarios based on state agency goals, regional transportation plans, or substituting half of short car trips with active travel
Air Pollution (fine particulate matter, PM2.5)	Data only available for SF Bay Area	Data available statewide and at each regional air basin

Chapter 1. Concept

The Integrated Transport and Health Impact Model (ITHIM) integrates travel and health data from multiple sources to predict changes in health and carbon emissions.[1-3]

Figure 1.1 ITHIM Integrates Data on Health and Travel



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.[4] The model's conceptual basis is comparative risk assessment.[5] It formulates a change in the burden of disease, *BD*, due to the shift in the exposure distribution from a baseline scenario to an alternative. This is an extension of the population attributable fraction (PAF) formula, in which an exposure, x, has a continuous distribution.

$$\Delta BD = \frac{\int_{\mathrm{Xmin}}^{\mathrm{Xmax}} RR(x)P(x)dx - \int_{\mathrm{Xmin}}^{\mathrm{Xmax}} RR(x)Q(x)dx}{\int_{\mathrm{Xmin}}^{\mathrm{Xmax}} RR(x)P(x)dx} \times BD_{Baseline}\,.$$

where,

$$PAF = \frac{\int_{\mathrm{Xmin}}^{\mathrm{Xmax}} RR(x)P(x)dx - \int_{\mathrm{Xmin}}^{\mathrm{Xmax}} RR(x)Q(x)dx}{\int_{\mathrm{Xmin}}^{\mathrm{Xmax}} RR(x)P(x)dx}$$

The relative risk, RR, at exposure level (x) is weighted by the baseline and alternative population distributions, P(x) and Q(x), respectively, and summed over all exposure levels. The burden of

disease can be measured by the number of deaths or a more comprehensive measure called disability adjusted life years (DALY), which are the sum of years of life lost due to premature mortality, YLL, and years of living with disability, YLD. This is illustrated below for a one individual in a population, but the measure is applied to all individuals in a population.

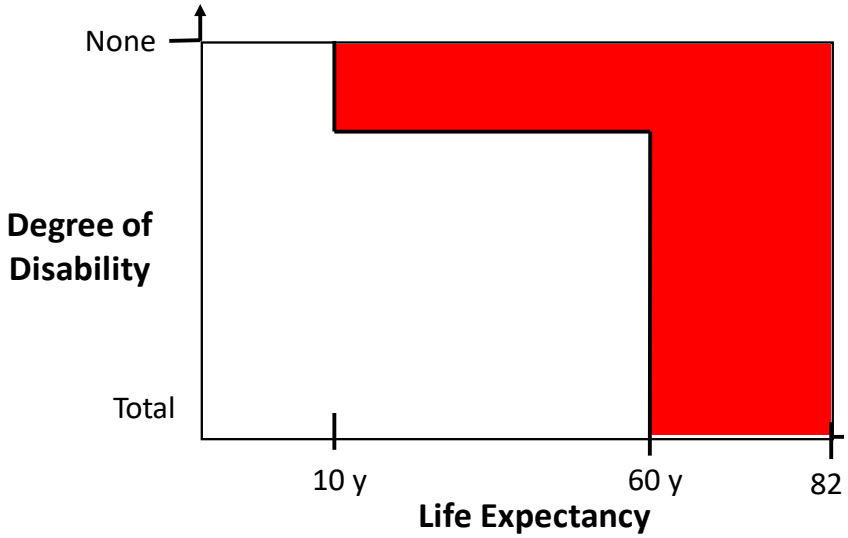


Figure 1.2 A woman who has a brain injury from a traffic collision at age 10 dies prematurely at age 60. Assuming a disability weight for injury at 0.63, her loss in DALYs is:

Years living with disability + years of life lost

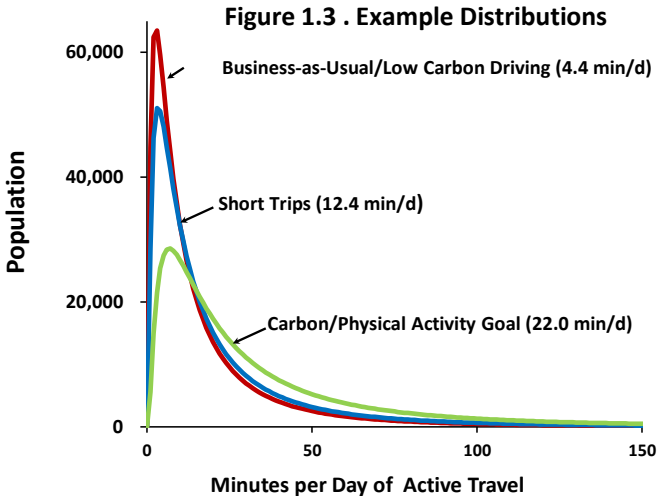
$(60y\text{-}10y) \times 0.63 + (82.5y - 60y) \times 1.0 = 15 + 31.5 = 46.5$ y

ITHIM incorporates specific causes that have strong evidence of a relative risk (RR)-exposure gradient for physical activity and air pollution, based on systematic reviews. These causes include cardiovascular diseases, colon cancer, breast cancer, lung cancer, respiratory disease, diabetes, and dementia.[6]

Exposure Distributions

Physical Activity

Physical activity includes both travel and non-travel related physical activity (PA). Activity times are multiplied by weights to give metabolic equivalent task hours (METS), which reflect energy expenditures for walking and cycling at average speeds and occupational tasks.[7] Idealized exposure distributions are illustrated in Figure 1.3.



The population distributions of PA are broken down by quintiles in gender and age groups (0-4, 5-14, 15-29, 30-44, 45-59, 60-69, 70-79, 80+ years).

Air Pollution

The distribution of fine particulate air pollution ($PM_{2.5}$) in populations is characterized by its mean, and the population attributable fraction is given by:

$$eq.\ 1 \qquad PAF = 1 - e^{\beta(x_0 - x_1)}$$

Where β is the coefficient for the dose-response gradient (*ln* RR) between the health outcome per unit of air pollution (e.g. $\mu g/m^3$) and x_0 is the baseline mean ambient concentration of $PM_{2.5}$ and x_1 is ambient mean concentration of $PM_{2.5}$ under the alternative scenario. (x_0 - x_1 are often represented by Δx, or change in $PM_{2.5}$ concentrations.) The means are expressed as population-weighted averages, which are outputs of two modeling processes: transportation emissions and chemical transport models.[8] Emissions models simulate the entire fleet of motorized vehicles and generate primary and secondary constituents of $PM_{2.5}$ (in tons/d). The chemical transport models integrate weather-related movement of air masses, fluid dynamics of the air shed, and photochemical reactions among primary and secondary constituents of transportation and non-transportation-related $PM_{2.5}$.

Because chemical transport models are complex and resource intensive, techniques are available to estimate health impacts as a function of emissions[9] rather than ambient $PM_{2.5}$ concentrations. These techniques take advantage of the observation that, in most air sheds across the United States, ambient $PM_{2.5}$ levels linearly track emissions levels of primary and secondary sources of PM2.5.

The Research Division of ARB has estimated mortality in using incidence per ton (IPT) of specific emissions applied to 2014-2106 populations in each of California's major air basins.

$$eq.\ 2 \qquad Incidence\ (deaths) = \sum_i^n c_i \times TPD_i$$

where the total incidence of deaths is the sum of product of tons per day (TPD) of pollutant i and a constant, c. The pollutants of interest are primary emissions of $PM_{2.5}$, including tire and brake wear, and nitrogen oxides (NO_x). Through the population attributable fraction (PAF) formula that underlies both the IPT and ITHIM, it is possible to equate emissions and $PM_{2.5}$ concentrations through an equivalency in deaths for the same air basin:

$$eq.\ 3 \qquad PAF \times BD = \Delta BD = \Delta\ Incidence\ (annual\ deaths)$$

where BD is the annual average burden of cardiorespiratory disease, 2014-2016.

The formula can be solved for change in $PM_{2.5}$ concentration per death:

$$eq.4 \qquad \Delta PM_{2.5} = \frac{\ln(1-\frac{1}{BD})}{\beta}$$

Likewise, the incidence per ton can be expressed per death ($1/c_i$). We can establish the relationship between emissions and air concentrations as a ratio by equating the two expressions (eq. 1 and eq. 4) for an equivalent number of deaths:

$$eq.5 \qquad Ratio_i = \frac{\Delta PM_{2.5}}{\Delta TPD_i} = \frac{\frac{\ln(1-\frac{1}{BD})}{\beta}}{\frac{1}{c_i}}$$

For regulatory purposes in 2009, the Research Division of the Air Resources Board calculated the average annual incidence of cardiorespiratory mortality per ton of emissions for diesel particulate matter (DPM) and nitrides of oxygen (NO_x). Using population and health data from 2014-2016, CARB updated the IPT data for air basins that correspond to regions as defined in ITHIM: San Francisco Bay Area, San Joaquin Valley, Sacramento Valley, South Coast (of Southern California), San Diego County, and the San Francisco Bay Area. It was assumed that direct emissions of car $PM_{2.5}$ are as potent as diesel particulate matter in cardiorespiratory mortality. The terms in equation 5 can be rearranged and summed for $PM_{2.5}$ and NO_x:

$$eq.6 \qquad \Delta PM_{2.5} = Ratio_{DPM} \times \Delta TPD_{direct\ car\ PM2.5} + Ratio_{NOx} \times \Delta TPD_{car\ NOx}$$

The change in car emissions, ΔTPD_i, is directly related to the change in vehicle miles traveled (VMT). By specifying the TPD as per percent change in car VMT, it is possible to predict ambient $PM_{2.5}$ levels as a function of percent change in car VMT. Estimated car emissions data for $PM_{2.5}$ and NO_x were obtained from 2010 to 2050 from the Emissions Factors (EMFAC2017) model. [10]

Carbon Emissions

The EMFAC emissions model also estimates carbon dioxide emitted per mile, EF (emissions factor), by vehicle and fuel type, and total vehicle miles traveled. Aggregate emissions are given by:

$$Aggregate\ CO_2\ Emissions = EF \times per\ capita\ mean\ car\ VMT \times Population.$$

In practice, CO_2 emission rates were VMT-weighted by fuel type (gas, diesel, and electric) of personal passenger vehicles (cars and light duty trucks) at five year intervals from 2010 to 2050. Corresponding populations were based on projections of the California Department of Finance. [11]

Road Traffic Injuries

For road traffic injuries (RTI), injuries per mile traveled by victim and striking vehicle for the baseline scenario, R_0, were formulated as a rate for each pair-wise combination of victim mode, *i*, and striking vehicle mode, *j* (Figure 1.4):

$$R_{0i,j} = \frac{\sum \text{Injuries}_{0i}}{(\sum \text{Personal Miles}_{0i} \times \text{Vehicle Miles}_{0j})^{0.5}}$$

Figure 1.4 Matrix of Striking Vehicle-Victim Road Traffic Injuries

			Number of Injuries/Fatalities					
			Striking Vehicle, SV					
Victim, V			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}	.	.	.	.	.

The victim and striking vehicle modes are pedestrian, bicyclist, motorcycle, car, bus, and truck. Because the relationship between traffic injuries and mode share of pedestrians and bicyclists is non-linear,[12] the denominator of injury rates incorporates the square root of the scenario distances traveled by collision victims and striking vehicles. The predicted number of injuries for a scenario is obtained by multiplying the baseline rate by the square root of the change in scenario distances traveled by victims and striking vehicles. The population attributable fraction is:

$$PAF = \frac{I_0 - I_S}{I_0}$$

Injury severity is categorized as fatal or serious, and is stratified by roadway type (highway, arterial, or local), which is a surrogate for traffic speed and volume associated with injury risk.

Joint and Total Impacts

Physical activity and $PM_{2.5}$ are both associated with mortality from all causes (combined) and the specific causes of ischemic heart disease, hypertensive heart disease, and stroke. When assessing the overall heath impact of these diseases, the population attributable fraction is based on multiplicative relative risks of physical activity and $PM_{2.5}$:

$$PAF = 1 - (RR_{PA} \times RR_{PM2.5})$$

The total change in the burden of disease combines the results for physical activity, air pollution and road traffic injuries:

$$\Delta BD_{total} = \Delta BD_{PA} + \Delta BD_{PM2.5} + \Delta BD_{RTI}$$

Monetization of Health Outcomes

The health benefits (and harms) due to the change in burden of disease and injury are presented as

monetized costs. Costs were estimated using two methods: 1) cost of illness and 2) willingness to pay using the value of a statistical life (VSL). For cost of illness, national estimates of direct medical costs and productivity losses (in constant 2010 dollars), obtained from specialty societies and government agencies, were scaled to the population of the scenario. Disease/injury specific change in PAFs were applied to costs. For VSL, the change in the number of deaths was multiplied by the dollar value of statistical life for VSL values used by different government agencies (Maizlish N, Siegel Z. *Monetizing Health Co-benefits from Transportation Strategies that Reduce Greenhouse Gas Emissions in the San Francisco Bay Area. Presented at the Annual Meeting of the American Public Health, San Francisco, October 21, 2012*. Richmond, CA: California Department of Public Health; 2012).

Data Sources

Health Outcomes

Deaths and DALYs for the United States in age-, sex- and cause-groups are publically available from the Global Burden of Disease database for 2010.[13] To account for differences in U.S. and health status in California regions, U.S. deaths and DALYs were scaled to California regional populations and adjusted using county mortality rates based on death certifications compiled by the California Department of Public Health.[14]

The GBD was also adjusted to take into account trends in population growth and disease rates from 2010 to 2050. The California population is projected to increase in size and have a proportionately greater share of older age groups. Advances in public health and medical care are projected to decrease age- and sex-specific rates of mortality due to chronic disease and injuries. County population estimates, broken down by age and sex from 2010 to 2050 in 5 calendar year intervals, were compiled from the California Department of Finance.[11] Estimated average annual percent change in sex- and age-specific disease rates for major chronic diseases and injuries were estimated by Canudas et al[15] from projections from the Social Security Administration and an expert panel. The annual percent change, APC, is applied to the Global Burden of Disease as follows, where t_1 is a future calendar year (up to 2050) and t_{2010} is the base year of 2010.

$$Deaths_{t_1} = Deaths_{2010} \times (1 - APC/100)^{(t_1 - t_{2010})}$$

The APC formula was applied to deaths, years of life lost, years living with disability, and disability adjusted life years.

Data on injuries was extracted from a public database of fatal and serious collisions reported to police[16, 17] (Statewide Integrated Traffic Reporting System, SWITRS, 2011-2015), which are geocoded to California's roadway network to determine the roadway type of each injury.

Travel Patterns

Age-and sex-specific travel times and distances for walking and bicycling are available from the California Household Travel Survey, 2012.[18] Travel distances for automobiles, trucks, buses, and rail were compiled from travel demand models and Environmental Impact Reports of California's largest metropolitan planning organizations (MPOs): Metropolitan Transportation Commission

(MTC), Sacramento Area Council of Governments (SACOG), Fresno Council of Governments (FresnoCOG), Southern California Association of Governments (SCAG), and San Diego County Association of Governments (SANDAG). These data are based on either 4-step or activity-based travel demand models (ABM) that simulate daily travel for every individual in the regional population. Data from the California Statewide Travel Demand Model and the California Household Travel Survey are also publicly available.

Non-Travel Physical Activity

For ischemic heart disease, stroke, hypertensive heart disease, and diabetes, the relationship between physical activity and disease rates for several health outcomes are based on studies that directly assessed walking and cycling apart from other physical activity. However, for dementia, depression, colon cancer and breast cancer, this dose-response relationship is based on total physical activity, which includes leisure, occupational, and domestic activities. Estimates of non-travel physical activity were derived from the California Health Interview Survey, 2009.[19]

Emissions

For the calculation of ambient $PM_{2.5}$ concentrations, emissions data on $PM_{2.5}$, NO_x, and CO_2 were obtained from the EMFAC2017 model[10] for all fuel types (gas, diesel, electric) of all personal passenger vehicles (light duty cars and trucks, LDA; LDT1, LDT2).

Assumptions and Limitations

ITHIM outputs occur at user-specified, steady-state time horizon. Several of the key assumptions of the ITHIM model are:

- The model assumes that the health co-benefits occur in a single "accounting year", although the changes in the physical activity distribution and low carbon driving are likely to gradually occur over time. It is assumed that the co-benefits will be maintained in subsequent years.
- Non-transport physical activity does not vary over time.
- Increases in physical activity due to active transport are not compensated by a decrease in non-transport physical activity (no activity substitution)
- Safety in numbers: the slope of square root relationship is a constant (i.e. does not account for infrastructure, policy, education, etc. that further deflects this slope).

Chapter References

1. Maizlish N, Linesch N, Woodcock J. Health and greenhouse gas mitigation benefits of ambitious expansion of cycling, walking, and transit in California. *J Transp Health.* 2017;http://dx.doi.org/10.1016/j.jth.2017.04.11.
2. Maizlish N, Woodcock J, Co S, Ostro B, Fairley D, Fanai A. Health cobenefits and transportation-related reductions in greenhouse gas emissions in the San Francisco Bay Area. *Am J Public Health.* 2013;103:703-709.
3. 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.

Supplemenary webappendix. *Lancet*. 2009;374:1930-1943.
4. Mueller N, David Rojas-Rueda D, Cole-Hunter T, de Nazelle A, Dons E, Gerike R, et al. Health impact assessment of active transportation: A systematic review. *Preventive Medicine*. 2015;76:103-114.
5. Ezzati M, Lopez AD, Rodgers A, Murray CJL. *Comparative Quantification of Health Risks: Global and Regional Burden of Disease Attributable to Selected Major Risk Factors*. Geneva: World Health Organization; 2004.www.who.int/healthinfo/global_burden_disease/cra/en/index.html.
6. Physical Activity Guidelines Advisory Committee. *2018 Physical Activity Guidelines Advisory Committee Scientific Report*. Washington, DC: U.S. Department of Health and Human Services; 2018.https://health.gov/paguidelines/second-edition/report/.
7. Ainsworth BE, Haskell WL, Whitt MC, et al. Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exercise*. 2000;32 (9 suppl):S498–504.
8. Hu J, Zhang H, Ying Q, Chen S, Vandenberghe F, Kleeman M. Long-term particulate matter modeling for health effect studies in California – Part 1: Model performance on temporal and spatial variations. *Atmos. Chem. Phys.* 2015;15:3445–3461.
9. Office of Air Quality Planning and Standards. *Technical Support Document: Estimating the Benefit per Ton of Reducing PM2.5 Precursors from 17 Sectors*. Research Triangle Park, NC: U.S. Environmental Protection Agency; 2018.https://www.epa.gov/sites/production/files/2018-02/documents/sourceapportionmentbpttsd_2018.pdf. Accessed March 9, 2019.
10. California Air Resources Board. *EMission FACtors (EMFAC) model, 2017*. Sacramento, CA: California Air Resources Board; 2017.http://www.arb.ca.gov/emfac/2017/.
11. Demographic Research Unit. *P-3: State and County Projections Dataset*. Sacramento, CA: California Department of Finance; 2019.http://www.dof.ca.gov/Forecasting/Demographics/Projections/P3_Complete.zip. Accessed August 9, 2019.
12. Jacobsen PL. Safety in numbers: more walkers and bicyclists, safer walking and bicycling. *Injury Prev*. 2003;9:205–209.
13. Institute for Health Metrics and Evaluation (IHME). *Global Burden of Disease (GBD)*. Seattle, WA: Institute for Health Metrics, University of Washington; 2015.http://www.healthdata.org/gbd.
14. Center for Health Statistics. *Vital Statistics Query System*. Sacramento, CA: California Department of Public Health; 2019.http://informaticsportal.cdph.ca.gov/chsi/vsqs/. Accessed April 2, 2019.
15. Canudas-Romo V, DuGoff E, Wu AW, Ahmed S, Anderson G. Life Expectancy in 2040: What Do Clinical Experts Expect? *North American Actuarial Journal*. 2016;20(3):276-285.
16. California Highway Patrol. *2008 Annual Report of Fatal and Injury Motor Vehicle Traffic Collisions. Statewide Integrated Traffic Records System (SWITRS)*. Sacramento: California Highway Patrol; 2008.www.chp.ca.gov/switrs/index.htm, accessed 8/2/2010.
17. Safety Transportation Research and Education Center. *Traffic Injury Mapping System*. Berkeley, CA: University of California; 2011.http://tims.berkeley.edu/index.php.
18. NuStats. *2010-2012 California Household Travel Survey Final Report*. Austin, TX: NuStats 2013.http://www.dot.ca.gov/hq/tpp/offices/omsp/statewide_travel_analysis/files/CHTS_Final_Report_June_2013.pdf.
19. UCLA Center for Health Policy Research. *California Health Interview Survey (CHIS)*. Los Angeles: University of California; 2005, 2009.http://healthpolicy.ucla.edu/chis/Pages/default.aspx.

Chapter 2. User's Guide to California ITHIM

Getting and Running the Application

California ITHIM is a computer program written in the free R programming language (version 3.6.1, July 2019)[20] and its Shiny package (version 1.2.1335).[21] R reads rows and columns of input data and performs mathematical calculations that are stored in output data structures (data frames and lists). Shiny is an extension of the R programming language that generates hypertext markup language (HTML), which is the standard for creating web pages. Shiny, with a standard style sheet (cascading style sheet, CSS) allows the styling and integration of photos, images, narrative text, tables, and graphs as a complete website.

There are three ways you can run California ITHIM:

1. Interactive Website

Just enter https://ww2.arb.ca.gov/ITHIM into your web browser (Chrome, Edge, Firefox, Internet Explorer, Opera, or Safari).

2. Developer Version

Advanced users may modify the R source code or use their own data files to create customized versions of ITHIM. Chapter 3 provides information on the application's directory structure, file names, and data file formats.

At the User Support page of California ITHIM (https://ww2.arb.ca.gov/ITHIM/#UserSupport#UserSupport), scroll to R & Shiny Code for Developers. Click on California ITHIM R/Shiny Application (ZIP). Unzip the file and copy the folders and files to a folder on your desktop computer. Running app.R, requires the prior installation of the R programming language (https://www.r-project.org) and several R packages (shiny, grid, png, markdown, digest, and ggplot2). R programming is facilitated by RStudio (https://www.rstudio.com/products/rstudio/download/), which is an integrated development environment.

3. Downloadable Application for Desktop Computers

For users without internet access, or for whom internet access is restricted by their organization, a downloadable version is available for desktop computers. At the User Support page of California ITHIM (https://ww2.arb.ca.gov/ITHIM/#UserSupport#UserSupport), scroll to "California ITHIM for Desktop Users." For computers running Windows, download the R/Shiny application from the https://ww2.arb.ca.gov/ITHIM/ ElectronShinyApp Windows.zip. For computers running the Apple (Mac) operating system, download the R/Shiny application from https://ww2.arb.ca.gov/ITHIM/ ElectronShinyApp Mac.zip

The downloadable applications appear nearly identical to the web-based version on a local browser. However, video tutorials, which require a connection to the internet, will not be active.

Devices that Run California ITHIM

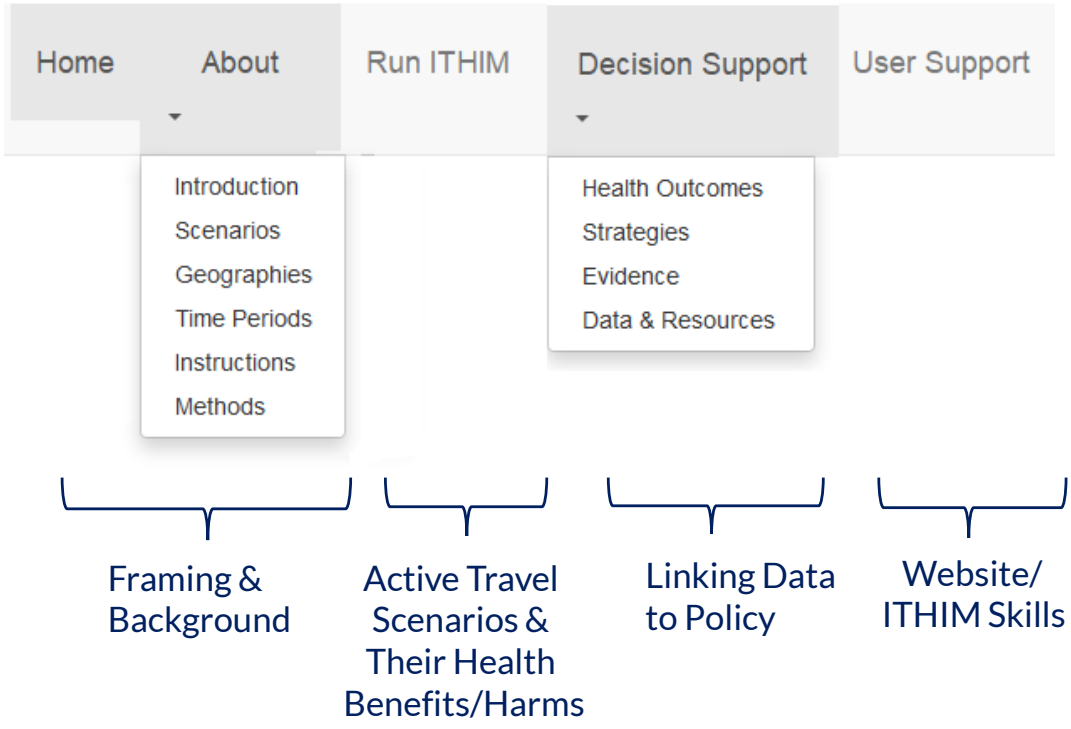
California ITHIM was designed for desktop and laptop computers running common web browsers (Chrome, Edge, Firefox, Internet Explorer, Opera, and Safari). Web page representations of the Home, About, Decision Support, and User Support pages may be acceptable on some mobile devices; however, the output of the RunITHIM interactive page may not be readable.

Organization of the California ITHIM Webpages

California ITHIM website follows a standard organization of web pages:

- Home
- About
- Tool
- Decision Support, and
- User Support (Figure 2.1).

Figure 2.1 Schematic of California ITHIM Software Application/Website



As you progress from left to right on the main horizontal navigation bar, you learn about: the framing of health, transportation, equity, and climate change; active travel scenarios and health co-benefits or harms; information that a) puts the co-benefits into a broader health and equity context and b) suggests on ways to increase physical activity, improve safety, and decrease air pollution, greenhouse gas emissions, and VMT in the transportation system; and, information to help you navigate the website and develop expertise in health impact analysis.

Website navigation may be done with a mouse or other pointing tool. Keyboard navigation, using the Tab, arrows, and Enter keys, is also available as an accessibility option.

Home Page

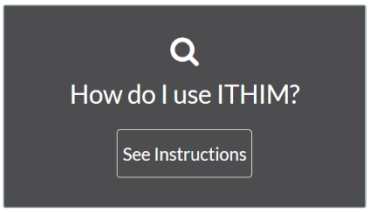
The Home Page (https://ww2.arb.ca.gov/ITHIM/) is the main landing page (Figure 2.2). The Home page introduces the website themes, action buttons that directly link to background information or the tool page, and a gallery of images that link to reports and publications featuring ITHIM.

Figure 2.2 Home Page Features of California ITHIM

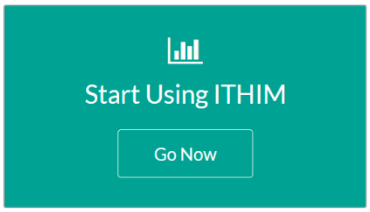
Clicking on the action buttons will link you directly to About and the RunITHIM pages.

Links: About > Introduction

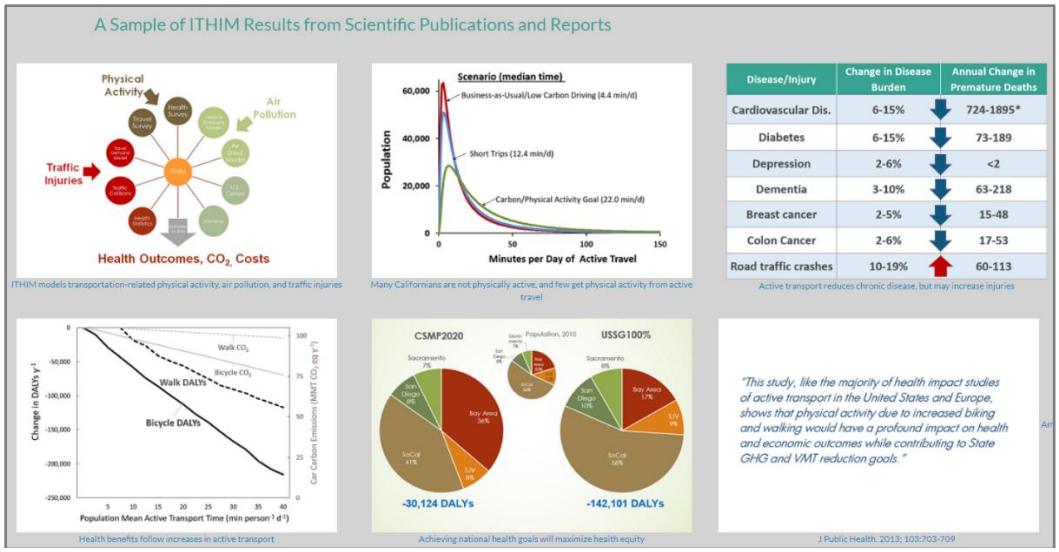
Links: About > Instructions



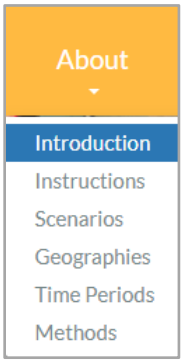
Kinks: RunITHIM (Tool Page)



Clicking on a gallery image will link you to technical reports and scientific publications featuring ITHIM.



About Pages



Clicking the About tab reveals 6 pages that provide an introduction, instructions on how to use the tool page, a description of 2010 baseline travel in California and different travel scenarios, the geographic scope of California ITHIM, time periods between 2010 and 2050 available for analysis, and highlights of the methods used in California ITHIM (Chapter 1).

Figure 2.3 Features of the About Pages

The About pages introduce the basic graphic style of web pages. A vertical, left side-panel with a gray background has a menu to navigate between the About pages. The right side-panel with a white background presents narrative content.

Introduction (https://ww2.arb.ca.gov/ITHIM/#Introduction)

About > Introduction is the landing page for the About pages. It describes the purpose and importance of ITHIM, its history, and use cases.

Instructions (https://ww2.arb.ca.gov/ITHIM/#Instructions)

Figure 2.4 Features of the About > Instructions

Instructions highlights three user selections that are required to generate output on the RunITHIM Page. These selections are:

- A scenario (among a picklist of 8 options)
- A geographic area of interest (among a picklist with entire State of California, five regions, or 30 individual counties).
- A time period of interest (among a picklist of eight 5-year time periods from 2010 to 2050).

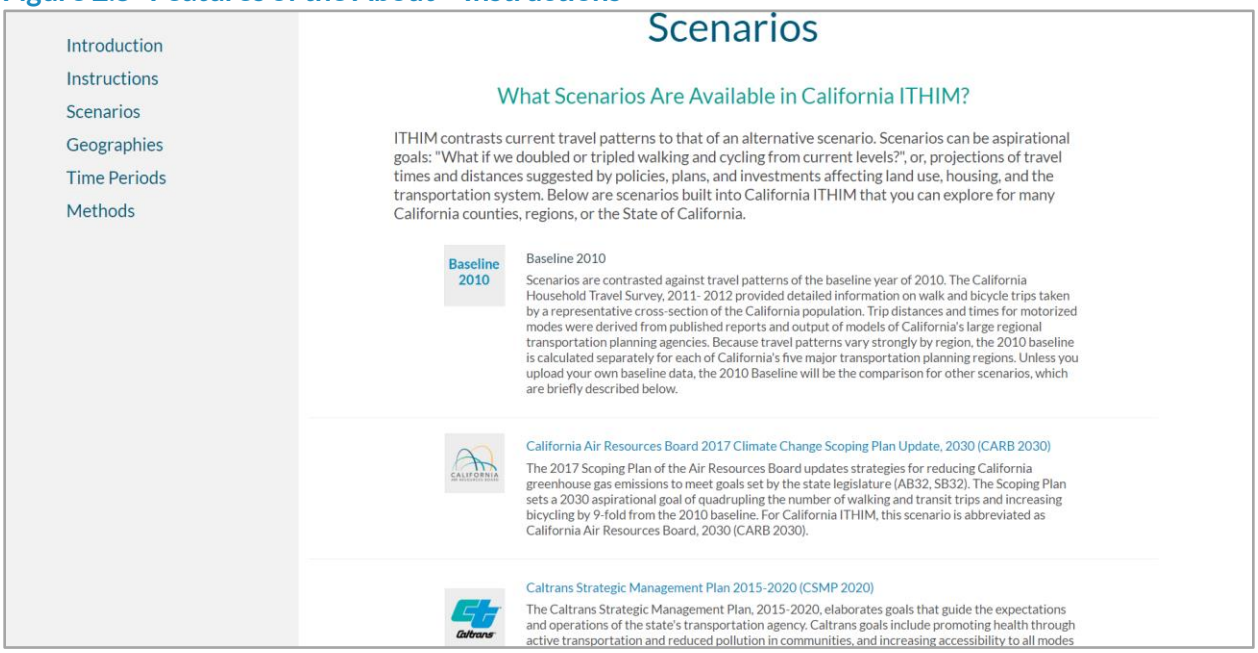
A detailed description of these options are covered in the RunITHIM page below.

Scenarios (https://ww2.arb.ca.gov/ITHIM/#Scenarios)

The Scenarios page (Figure 2.5) lists and describes the 2010 Baseline and 8 alternative travel scenarios based on state agency goals for mobility and greenhouse gas reductions, regional transportation plans, national health goals for physical activity, and several "What If" options. The "What If" options:

- Increase or decrease walking, cycling, and transit by multiples or a percentage of the baseline
- Increase or decrease walking and/or cycling by a fixed amount of time per week
- Substitute short car trips < 5 miles in the 2010 baseline with walking (<1 miles) or cycling (1-5 miles).

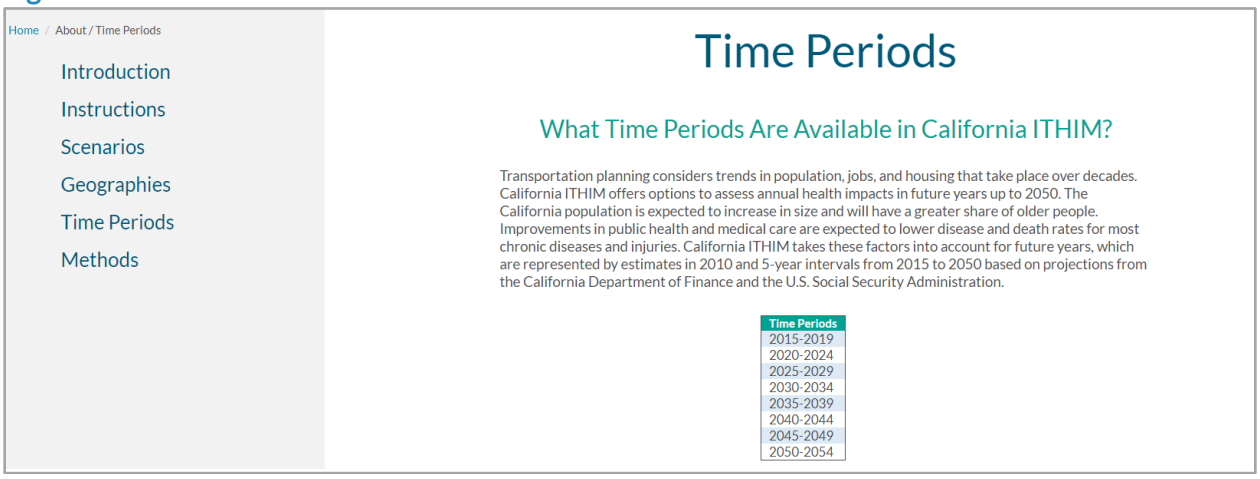
Figure 2.5 Features of the About > Instructions



A summary of the Scenarios are listed in Table 2.1.

Time Periods (https://ww2.arb.ca.gov/ITHIM/#TimePeriods)

Figure 2.6 Features of the About > Time Periods



California ITHIM incorporates California's expected population growth, demographic trends of aging, and mortality trends over time. These changes impact both travel patterns and California's burden of disease. In 5-year time intervals between 2010 and 2050, users can match the time period of scenario implementation with the expected population and disease trends.

Table 2.1 Baseline and Scenarios in California ITHIM

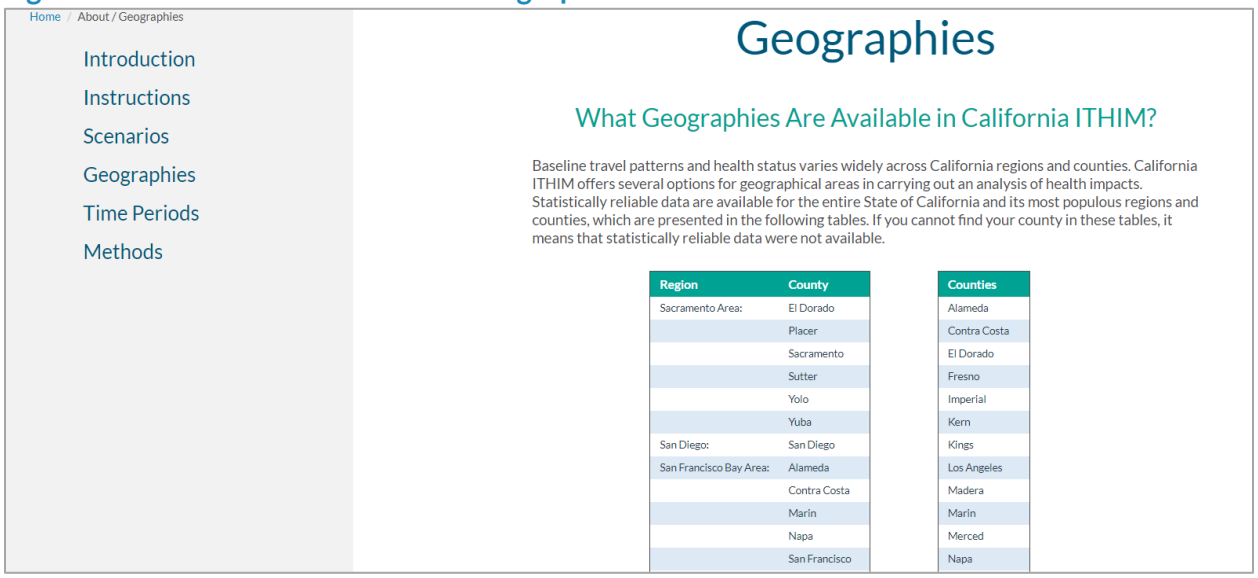
Scenario Name	Description
Baseline 2010	Scenarios are contrasted against travel patterns of the baseline year of 2010. The California Household Travel Survey, 2011-2012 provided detailed information on walk and bicycle trips taken by a representative cross-section of the California population. Trip distances and times for motorized modes were derived from published reports and output of models of California's large regional transportation planning agencies. Because travel patterns vary strongly by region, the 2010 baseline is calculated separately for each of California's five major transportation planning regions. Unless you upload your own baseline data, the 2010 Baseline will be the comparison for other scenarios, which are briefly described below.
CARB 2030	The 2017 Scoping Plan of the Air Resources Board updates strategies for reducing California greenhouse gas emissions to meet goals set by the state legislature (AB32, SB32). The Scoping Plan sets a 2030 aspirational goal of quadrupling the number of walking and transit trips and increasing bicycling by 9-fold from the 2010 baseline.
Caltrans Strategic Management Plan, 2015-2020 (CSMP 2020)	The Caltrans Strategic Management Plan, 2015-2020, elaborates goals that guide the expectations and operations of the state's transportation agency. Caltrans goals include promoting health through active transportation and reduced pollution in communities, and increasing accessibility to all modes of transportation. The plan sets 2020 targets for doubling walking and transit and tripling bicycling from a 2010 baseline.
Sustainable Communities Strategies, 2040 (SCS 2040)	California's regional transportation planning agencies (called metropolitan planning organizations, MPOs) create updates every 4 years to their long-range transportation plans. The plans consider regional mobility goals for all modes of travel and are required to accommodate population growth and housing needs over a 20 to 25 year planning period. In 2008, the State legislature required that the regional plans reduce per capita transportation-related greenhouse gas emissions through land use strategies that reduce car commuting. These include greater reliance on active travel and transit, and "compact growth" or "smart growth" in which new housing is built along transportation corridors and transit assets. The travel patterns in the most recent approved scenarios of the largest MPOs are inputs to ITHIM.

Table 2.1 Baseline and Scenarios in California ITHIM (continued)

Scenario Name	Description
U.S. Surgeon General Recommendations (USSG)	Popularly known as "the Nation's Doctor", the U.S. Surgeon General focuses on improving the country's health. Based on a review of decades of research on the relationship between physical activity and health, the Surgeon General has stated that "engaging in regular physical activity is one of the most important things that people of all ages can do to improve their health." For adults, an optimum level of health can be achieved by engaging in at least 150 minutes of moderate-intensity physical activity each week. For California ITHIM this recommendation has been translated into a population health goal in which at least 50% of Californians get 150 minutes per week of moderate physical activity through active transportation. In 2010, only 7% of Californians met this goal.
Baseline Multiples	This is a "What-If" Scenario in which you can assess the health impacts of increasing the average baseline walking and cycling for transport by relative amounts. In the CARB 2030 and CSMP 2020 scenarios we increased walking and transit by a factor of 2 or 4, respectively. This scenario allows you to input any multiple of the regional baseline average of walking, cycling, or transit.
Fixed Time	This is a "What-if" scenario allows you to specify the average weekly minutes of walking and cycling for transport.
Short Trips	Nearly two-thirds of all car trips in California are less than 5 miles. In this scenario, we envision half of these trips are walked or bicycled. Trips less than 1 miles are walked (20 minutes per day), and trips 1 to 5 miles are cycled (6 to 30 minutes per day).
Low Carbon Driving (LCD)	Car travel reflects a significant increase in electric vehicles, hybrids, and low carbon fuels. This scenario assumes there is no change from baseline in total car vehicle miles traveled or levels of active transportation. In addition to significantly lowering greenhouse gas emissions from cars, low carbon driving reduces health risks from fine particulate matter.
User Upload and Equity Analyses	If you or your organization have access to a travel or land use model, you can assess the health impacts of your own baseline, business-a-usual, and other scenarios by uploading travel distances and times for different modes of travel. Likewise, data can be uploaded to carry out analyses of population subgroups based on race/ethnicity, income, and other factors that influence health equity. Details on how to prepare files for uploading and equity analyses are described in Chapter 2 and Appendix C of this manual.

Geographies (https://ww2.arb.ca.gov/ITHIM/#Geographies)

Figure 2.6 Features of the About > Geographies



The Baseline 2010 and scenarios have been calibrated for the populations of five geographic regions of California, which are pooled for statewide analyses. The health outcomes, costs, and carbon emissions are scaled to county populations within these regions based on the population size and age and sex composition of the county. The counties and regions for which statistically reliable data are available are presented in Table 2.2 (next page). Counties not listed do not have statistically reliable data on bicycling by age and gender in the data source (California Household Survey, 2012).

Methods (https://ww2.arb.ca.gov/ITHIM/#Methods)

Figure 2.8 Features of the About > Methods

Table 2.2 Geographic Scope of ITHIM Regions

Region	County
Sacramento Area:	El Dorado
	Placer
	Sacramento
	Sutter
	Yolo
	Yuba
San Diego:	San Diego
San Francisco Bay Area:	Alameda
	Contra Costa
	Marin
	Napa
	San Francisco
	San Mateo
	Santa Clara
	Solano
	Sonoma
San Joaquin Valley:	Fresno
	Kern
	Kings
	Madera
	Merced
	San Joaquin
	Stanislaus
	Tulare
Southern California:	Imperial
	Los Angeles
	Orange
	Riverside
	San Bernardino
	Ventura

The Methods page gives an overview of the statistical methods used to quantify the health impacts of changes in the distribution of physical activity, air pollution, and traffic collision due to changes in travel patterns from a baseline to the scenario chosen by the user. The methods also highlight key assumptions and limitations. Additional details of the methods appear in Chapter 1 of this *User's Guide*.

RunITHIM Page

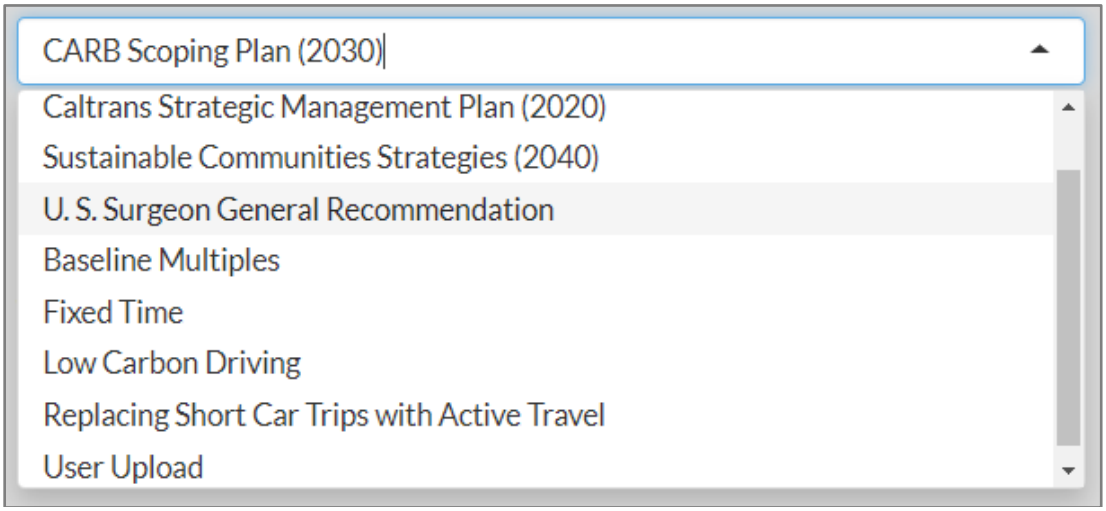
Figure 2.9 Features of the RunITHIM page

The RunITHIM page (https://ww2.arb.ca.gov/ITHIM/#RunITHIM) is an interactive tool in which user-selected options drive the type and level of detail of outputs. The screen is divided into a gray-shaded left side-panel with user options and a wider right side-panel for outputs. To generate output, users must select a scenario, a geographic area, and a time period. The defaults are set for a statewide analysis of the CARB 2030 Scenario (contrasted with the Baseline 2010), evaluated in the year 2010.

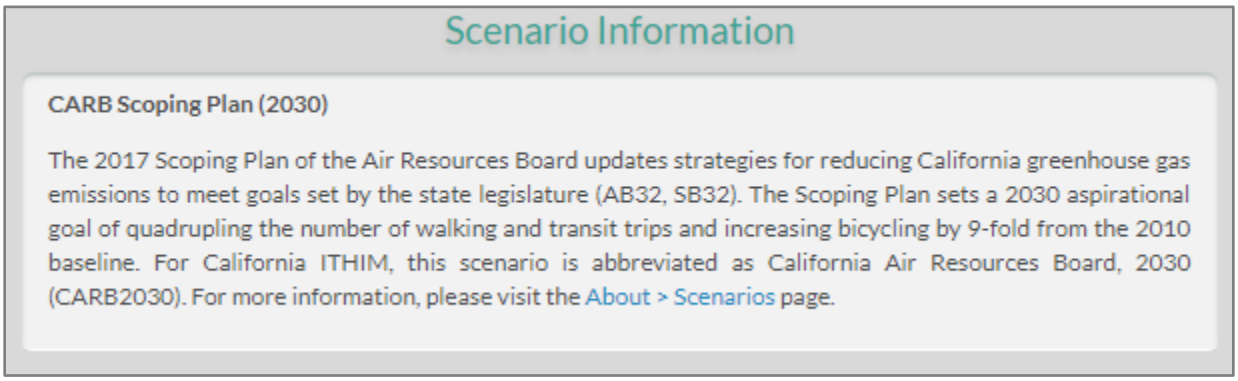
Figure 2.10 RunITHIM User Interface: Left-Side panel for Options, Right-Side Panel for Outputs

Scenarios

The scenario list is revealed by clicking on the arrow at the end of the **Scenarios** dialogue box. Use the scroll bar to the right side of the dialogue box to scroll through the entire list.



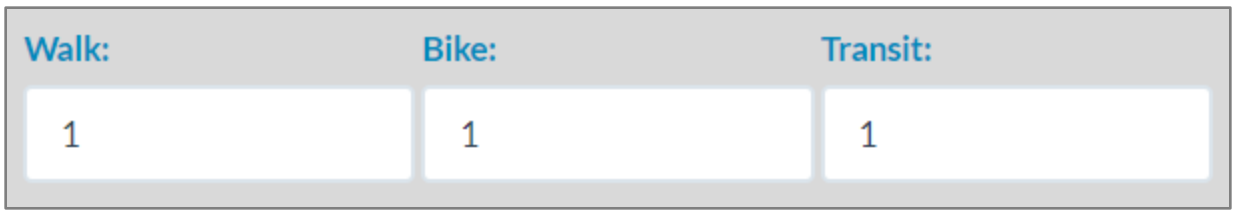
You can move through the list with your mouse (which moves the cursor) or press the down arrow key on your keyboard. When the focus changes, the background of specific list items turns gray. When you click on an item or press the <Enter> key, the choice is activated and the Scenarios dialogue box will close and show the selection. The same scenario description that appeared in the About pages will also appear in the left side-panel.



This sequence for selecting a scenario applies to all the scenarios. However, "Baseline Multiples", "Fixed Time", and "User Upload" require additional user inputs.

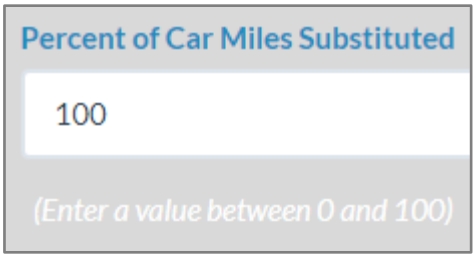
Baseline Multiples

This scenario allows you to make increases in per capita mean walking, bicycling, or transit relative to levels of those in the Baseline 2010. When you select this scenario, an additional dialogue box appears.



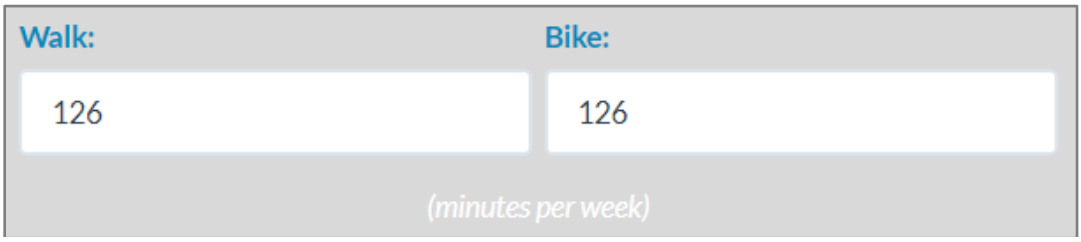
The default multiples are 1, meaning the scenario starts off with baseline levels of walking, cycling, and transit. If you would like to explore the health impacts of doubling walking, enter 2 in the box under Walk. For three times the baseline, enter 3. For an increase of 25%, enter 1.25, and for an increase of 1%, enter 1.01. Bike and transit work the same way. Transit means bus, trains, and light rail.

By default, the increases in active travel in "Baseline Multiples" replace car trips mile-for-mile. This is indicated in the dialogue box, as 100% of Car Miles Substituted. However, you may modify the scenario for less than a mile-for-mile replacement. For example, if only half of car trips were substituted by active travel, you would enter 50 into the dialogue box.



Fixed Time

In addition to relative changes in baseline levels, you can indicate a specific amount of walking or cycling time in your population (geography) of interest. The amount is expressed as per capita mean minutes per week. When you select "Fixed Time", another dialogue box will appear below the Scenario.

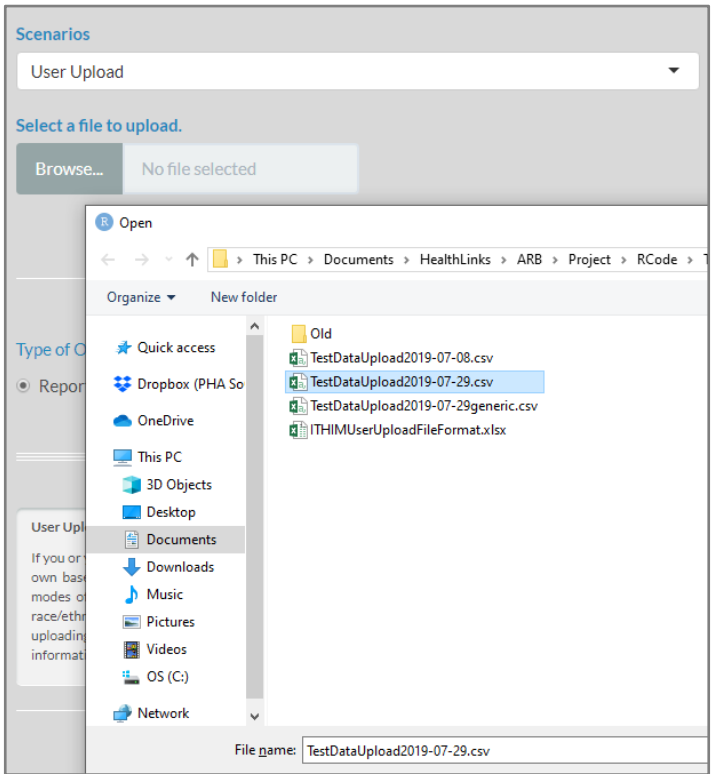


You can enter any amount of time for walking or cycling up to 150 minutes per person per week. This upper limit reflects concerns that exceeding this limit may place a serious time burden on a large share of the population and compete with economic and social necessities.

User Upload

For users with their own data on baseline, business-as-usual, or alternative scenarios, this option allows you to upload data from your desktop computer. Uploading data for equity analyses follow the same steps, but with data specific to the equity group of interest (e.g., race/ethnicity, income, etc.). When you chose this option, a new dialogue box will appear.

Figure 2.11 Dialogue Box for Uploading a File with Baseline, Business-as-Usual, and Scenario Data



When you click on the Browse button, you will open a directory of file folders on your desktop computer. Use the commands in your computer's operating system to navigate to the folder that contains the file you would like to upload. In the example above (from Windows 10 operating system), you can click on the file and the Open button to load the data into California ITHIM. The format of the data must follow a standard template as a CSV (commas separated values) file. Files in other formats cannot be read into California ITHIM. The file format and template are presented in Tables 2. 3 and 2. 4, respectively (next page). If the files do not contain format errors, new buttons will appear in the dialogue so you can indicate the ID numbers of the Baseline/BAU and Scenario data. (Baseline usually indicates empirical data from a specific year. Business-as-Usual (BAU) usually means travel projections to a future year based on current trends or plans, not new travel scenarios). After you make selections, a table will appear with the selected data. For uploaded files that contain errors or missing data, messages will appear to help users identify problematic fields or unreadable data (Table 2.5).

Figure 2.12 Selecting the Baseline, Business-As-Usual, and Alternative Scenario from User Uploaded Data

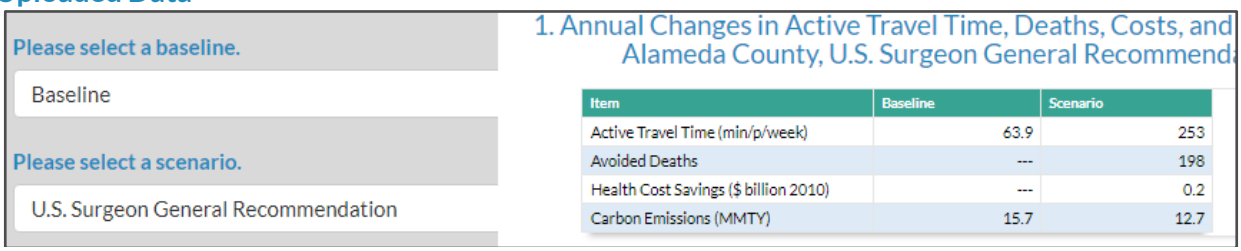


Table 2.3 Template of a File to Upload Data on Baseline, Business as Usual and Scenario Travel Patterns

1	Region	item_name	ScenarioID	Mode	strata	item_result
50	SF Bay Area	Per Capita Mean Daily Travel Distance	Baseline2010	Bike		0.087156787
51	SF Bay Area	Per Capita Mean Daily Travel Distance	Baseline2010	Bus		0.593850807
52	SF Bay Area	Per Capita Mean Daily Travel Distance	Baseline2010	CarDriver		15.63229075
53	SF Bay Area	Per Capita Mean Daily Travel Distance	Baseline2010	CarPassenger		5.029914916
54	SF Bay Area	Per Capita Mean Daily Travel Distance	Baseline2010	Motorcycle		0.124415584
55	SF Bay Area	Per Capita Mean Daily Travel Distance	Baseline2010	Rail		1.056315744
56	SF Bay Area	Per Capita Mean Daily Travel Distance	Baseline2010	Walk		0.423905688
57	SF Bay Area	Proportion of Vehicle Miles by Mode and Facility Type	Baseline2010	Bus	arterial	0.239335182
58	SF Bay Area	Proportion of Vehicle Miles by Mode and Facility Type	Baseline2010	Bus	highway	0.690514883
59	SF Bay Area	Proportion of Vehicle Miles by Mode and Facility Type	Baseline2010	Bus	local	0.070149935
60	SF Bay Area	Proportion of Vehicle Miles by Mode and Facility Type	Baseline2010	Car	arterial	0.284806285
61	SF Bay Area	Proportion of Vehicle Miles by Mode and Facility Type	Baseline2010	Car	highway	0.636418672
62	SF Bay Area	Proportion of Vehicle Miles by Mode and Facility Type	Baseline2010	Car	local	0.078775043
63	SF Bay Area	Proportion of Vehicle Miles by Mode and Facility Type	Baseline2010	Truck	arterial	0.239335182
64	SF Bay Area	Proportion of Vehicle Miles by Mode and Facility Type	Baseline2010	Truck	highway	0.690514883
65	SF Bay Area	Proportion of Vehicle Miles by Mode and Facility Type	Baseline2010	Truck	local	0.070149935
66	SF Bay Area	Per Capita Mean Daily Travel Distance	BAU2040	Bike		0.086433332
67	SF Bay Area	Per Capita Mean Daily Travel Distance	BAU2040	Bus		0.282430577
68	SF Bay Area	Per Capita Mean Daily Travel Distance	BAU2040	CarDriver		13.90619267
69	SF Bay Area	Per Capita Mean Daily Travel Distance	BAU2040	CarPassenger		4.649418104
70	SF Bay Area	Per Capita Mean Daily Travel Distance	BAU2040	Motorcycle		0.124415584
71	SF Bay Area	Per Capita Mean Daily Travel Distance	BAU2040	Rail		0.553941829
72	SF Bay Area	Per Capita Mean Daily Travel Distance	BAU2040	Walk		0.449455623
73	SF Bay Area	Proportion of Vehicle Miles by Mode and Facility Type	BAU2040	Bus	arterial	0.252611108
74	SF Bay Area	Proportion of Vehicle Miles by Mode and Facility Type	BAU2040	Bus	highway	0.672340142
75	SF Bay Area	Proportion of Vehicle Miles by Mode and Facility Type	BAU2040	Bus	local	0.07504875
76	SF Bay Area	Proportion of Vehicle Miles by Mode and Facility Type	BAU2040	Car	arterial	0.28830773
77	SF Bay Area	Proportion of Vehicle Miles by Mode and Facility Type	BAU2040	Car	highway	0.630592426
78	SF Bay Area	Proportion of Vehicle Miles by Mode and Facility Type	BAU2040	Car	local	0.081099844
79	SF Bay Area	Proportion of Vehicle Miles by Mode and Facility Type	BAU2040	Truck	arterial	0.252611108
80	SF Bay Area	Proportion of Vehicle Miles by Mode and Facility Type	BAU2040	Truck	highway	0.672340142
81	SF Bay Area	Proportion of Vehicle Miles by Mode and Facility Type	BAU2040	Truck	local	0.07504875
82	SF Bay Area	Per Capita Mean Daily Travel Distance	Scenario3	Bike		0.086433332
83	SF Bay Area	Per Capita Mean Daily Travel Distance	Scenario3	Bus		0.282430577
84	SF Bay Area	Per Capita Mean Daily Travel Distance	Scenario3	CarDriver		13.90619267
85	SF Bay Area	Per Capita Mean Daily Travel Distance	Scenario3	CarPassenger		4.649418104
86	SF Bay Area	Per Capita Mean Daily Travel Distance	Scenario3	Motorcycle		0.124415584
87	SF Bay Area	Per Capita Mean Daily Travel Distance	Scenario3	Rail		0.553941829
88	SF Bay Area	Per Capita Mean Daily Travel Distance	Scenario3	Walk		0.449455623
89	SF Bay Area	Proportion of Vehicle Miles by Mode and Facility Type	Scenario3	Bus	arterial	0.252611108
90	SF Bay Area	Proportion of Vehicle Miles by Mode and Facility Type	Scenario3	Bus	highway	0.672340142
91	SF Bay Area	Proportion of Vehicle Miles by Mode and Facility Type	Scenario3	Bus	local	0.07504875
92	SF Bay Area	Proportion of Vehicle Miles by Mode and Facility Type	Scenario3	Car	arterial	0.28830773
93	SF Bay Area	Proportion of Vehicle Miles by Mode and Facility Type	Scenario3	Car	highway	0.630592426
94	SF Bay Area	Proportion of Vehicle Miles by Mode and Facility Type	Scenario3	Car	local	0.081099844
95	SF Bay Area	Proportion of Vehicle Miles by Mode and Facility Type	Scenario3	Truck	arterial	0.252611108
96	SF Bay Area	Proportion of Vehicle Miles by Mode and Facility Type	Scenario3	Truck	highway	0.672340142
97	SF Bay Area	Proportion of Vehicle Miles by Mode and Facility Type	Scenario3	Truck	local	0.07504875

The data dictionary for the template is presented below.

Table 2.4 Data Dictionary for Uploaded Data Files

Variable Name	Definition	Code Levels
Region	California and 5 MPO regions	California; SF Bay Area; San Joaquin Valley; Sacramento Area; Southern California; San Diego County
Item_Name	Distance Travel by mode or Proportion of Distance by Facility Type	"Per Capita Mean Daily Travel Distance" or "Proportion of Vehicle Miles by Mode and Facility Type"
Scenario_ID	User defined alphanumeric string to identify baseline, BAU, or scenario	
Mode	Travel mode	Walk, Bike, CarDriver, CarPassenger, Bus, Rail, Motorcycle, Truck
Strata	Facility type for Item_Name Proportion of Vehicle Miles by Mode and Facility Type	local, arterial, highway for bus, car, truck modes only
Item_Result	Per capita mean miles/p/day by mode	10 decimal digit precision

Geographies

You may choose one geographical population from the Geographies pick list. The default geography is the entire state of California, which is the first item in the list. The pick list then presents five major California regions, and 30 individual counties in alphabetic order. (See About Page > Geographies for the counties that make up regions.) You can use the scroll bar on the right side of the pick list box to review all the items. Clicking on an item (or pressing the <Enter> key, will cause the pick list to close and reveal your choice in the selection box.

Figure 2.13 Selecting Geographies

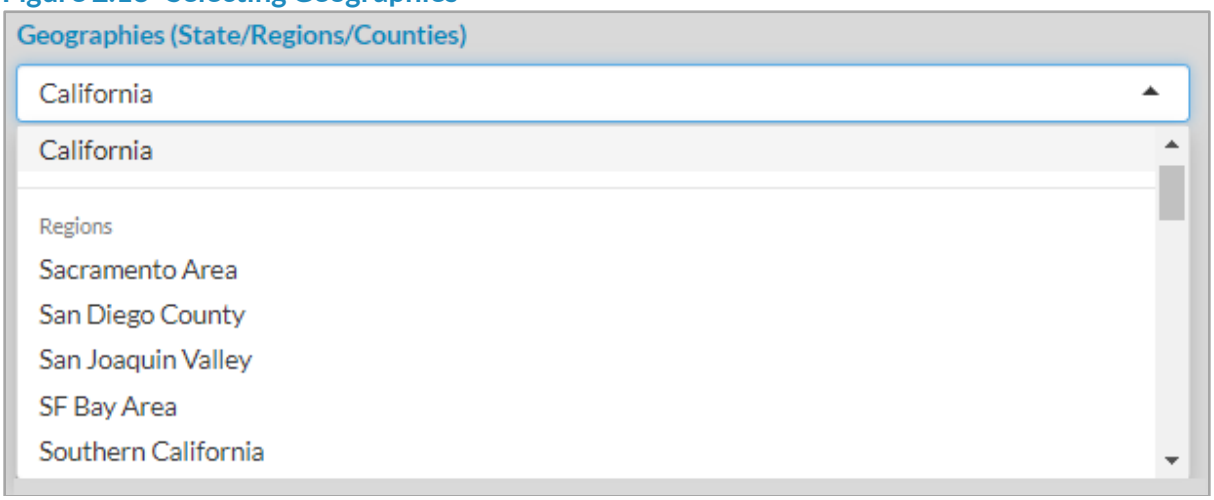
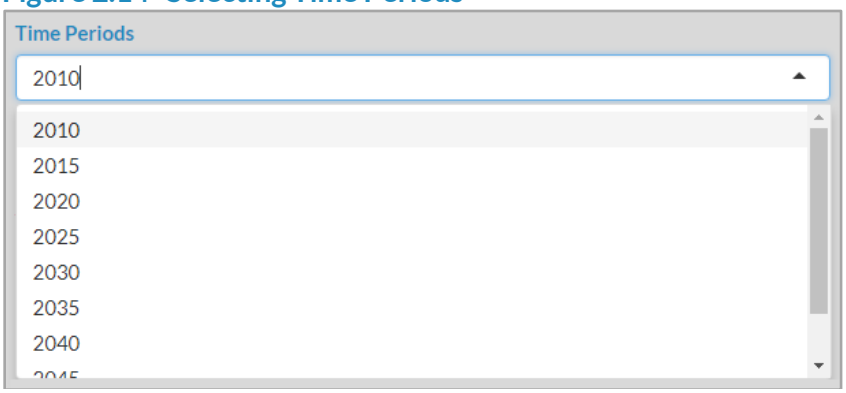


Table 2.5. Examples of Errors and Warning Messages in User Data Uploads

Type of Error/Warning	Example Warning Message	Data File
Column headings	User Error: Headers are incorrect. Missing Mode.	C: Scenario_ID; D: ; E: Strata Baseline; Bike Baseline; Bus Baseline; CarDriver
Item_Name	User Error: Missing "Per Capita Mean Daily Travel Distance" for Baseline in user uploaded data (csv).	Item_Name Per Capita Mean Daily Travel Distances Per Capita Mean Daily Travel Distance Per Capita Mean Daily Travel Distance
Region (misspell/ missing)	User Error: The Scenario_ID "Baseline" has either a missing Region value, or contains multiple values in Region.csv).	Region San Diego County SF Bay Area SF Bay Area
Mode duplicated/ missing	User Error: The Scenario_ID "Baseline" has an excess or missing "Mode" in Distances in user uploaded data (csv)."	D: Mode; E: Strata; F: Item_Result ; ; 0.168492 Bus; ; 0.804299 CarDriver; ; 15.57071
Item_Result missing (or missing row)	User Error: The Scenario_ID "Baseline" is missing or duplicating mode: Bike.	Mode; Strata; Item_Result Bike; ; Bus; ; 0.804299
Missing motorcycle/bus	Warning: The Scenario_ID "Baseline" is missing values for mode: Bus. Thus, substituting values from ITHIM TOOL's Baseline 2010.	D: Mode; E: Strata; F: Item_Result Bike; ; 0.168492 Bus; ; CarDriver; ; 15.57071

Time Periods

Figure 2.14 Selecting Time Periods

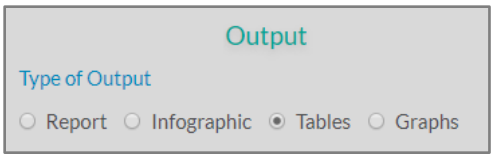


You may choose one time period from the Time Periods pick list. The time period aligns the projected time period for implementing the scenario and projected population characteristics.

The default time period is 2010, which is the first item in the list. The pick list then presents eight years in 5-year intervals from 2015 to 2050. You can use the scroll bar on the right side of the pick list box to review all the items. Clicking on an item (or pressing the <Enter> key, will cause the pick list to close and reveal your choice in the selection box.

Output Formats

Figure 2.14 Choices for Outputs



By clicking on a radio button, you may choose among four options for output formats.

Report

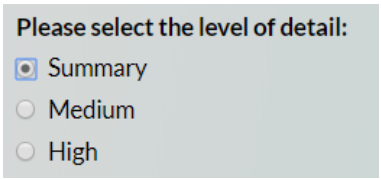
The Report the default output format and appears in the right side panel (Figure 2.15). The Report is a graphical mini-report similar in content to a bulleted list of talking points, or an elevator pitch. It is prefaced by a general statement on the health impacts of increases in active travel, and describes the main findings of the health impact analysis: changes in active travel from the baseline to the chosen scenario, annual health impacts, and emissions of carbon dioxide and $PM_{2.5}$. The "breadcrumbs" of selection –scenario, geography, and time period – are embedded in the first line after the preface.

Infographic

The infographic is a graphic that weaves together narrative, images, and the health and environmental impacts of a selected scenario, geography, and time period (Figure 2.16, next page). The impacts are compared with those of two other scenarios that approximate 1) the upper limit of optimal health gains from following the U.S. Surgeon General physical activity guidelines and 2) the upper limit of carbon and air pollution reductions by implementation of low carbon driving strategies (e.g. electrification of the automobile fleet, low carbon fuel standard, etc.).

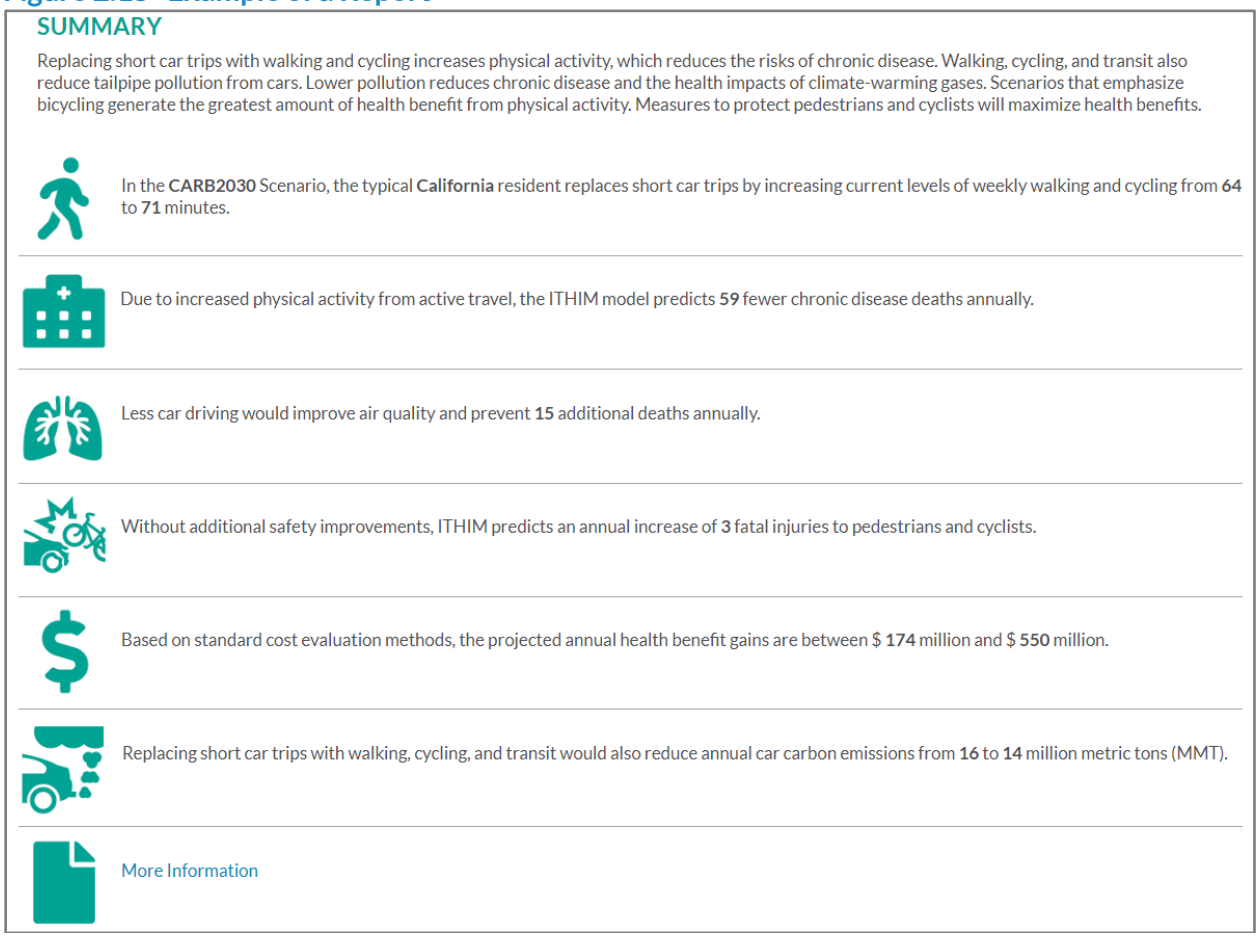
Tables and Graphs

The Tables selection generates formatted tables for the selected scenario, geography, and time period. Likewise, The Graphs selection generates bar graphs and multi-series line graphs for the selected scenario, geography, and time period. When Tables or Graphs are selected, another set of radio buttons will appear below.



Use these radio buttons to select the level of detail in the tables and graphs that appears in the right side-panel. Each level of detail is represented by 4 to 6 different tables or graphs. (Figure 2.17-18)

Figure 2.15 Example of a Report



SUMMARY

Replacing short car trips with walking and cycling increases physical activity, which reduces the risks of chronic disease. Walking, cycling, and transit also reduce tailpipe pollution from cars. Lower pollution reduces chronic disease and the health impacts of climate-warming gases. Scenarios that emphasize bicycling generate the greatest amount of health benefit from physical activity. Measures to protect pedestrians and cyclists will maximize health benefits.

In the **CARB2030** Scenario, the typical **California** resident replaces short car trips by increasing current levels of weekly walking and cycling from **64** to **71** minutes.

Due to increased physical activity from active travel, the ITHIM model predicts **59** fewer chronic disease deaths annually.

Less car driving would improve air quality and prevent **15** additional deaths annually.

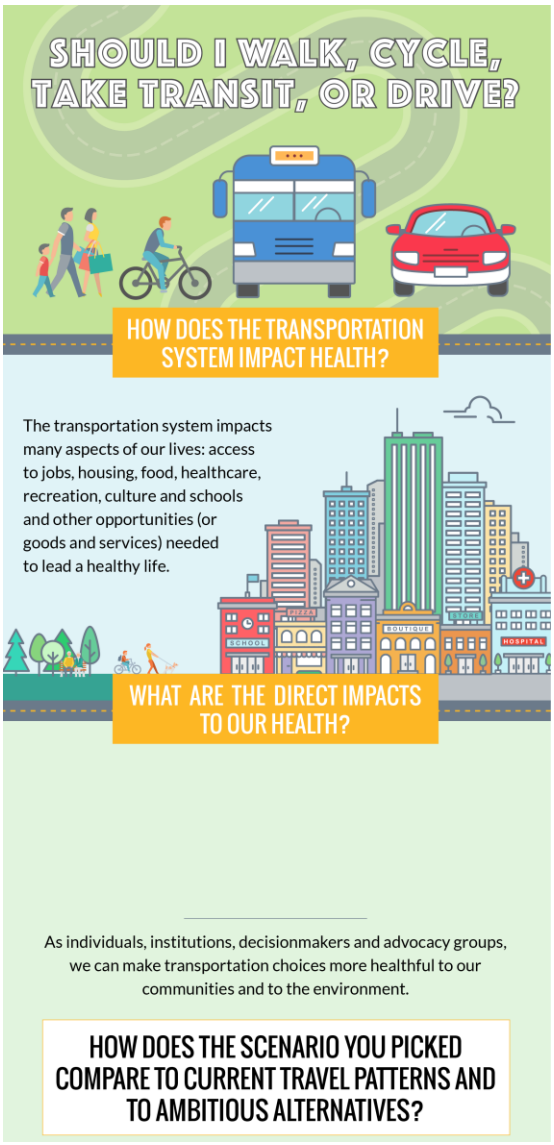
Without additional safety improvements, ITHIM predicts an annual increase of **3** fatal injuries to pedestrians and cyclists.

Based on standard cost evaluation methods, the projected annual health benefit gains are between $ **174** million and $ **550** million.

Replacing short car trips with walking, cycling, and transit would also reduce annual car carbon emissions from **16** to **14** million metric tons (MMT).

More Information

Figure 2.16 Example of the Infographic*



* On computer screens, the infographic is one column wide, but is displayed above to fit this page.

Figure 2.17 Example of Table Output (Summary Level)

Annual Changes in Active Travel Time, Deaths, Costs, and Carbon Emissions, California , CARB2030

Item	Baseline	Scenario
Active Travel Time (min/p/w)	63.7	71.4
Avoided Deaths	---	86.0
Health Cost Savings ($ billion 2010)	---	0.2
Carbon Emissions (MMTY)	15.7	14.2

Per Capita Mean Weekly Active Travel Times (minutes), California , CARB2030

Mode	Baseline	Scenario
Walk	57.8	64.3
Bike	5.9	7.1
Total	63.7	71.4

Per Capita Mean Annual Travel Distance (miles) by Mode, California , CARB2030

Mode	Baseline	Scenario
Active	212.2	240.6
Car	7507.4	6825.4
Transit	648.0	906.3
Total (incl. Truck & Motorcyle)	9092.7	8697.4

Annual Change in the Burden of Disease by Health Pathway, California , CARB2030

Pathway	PAF.Deaths	Deaths.Avoided	PAF.Dalys	Dalys.Avoided
Physical Activity	0.3	58.6	0.4	1443.4
Air Pollution	0.1	14.5	0.1	193.0
Road Traffic Injuries	2.8	12.8	2.8	657.3
Total	0.3	86.0	2.8	2293.7

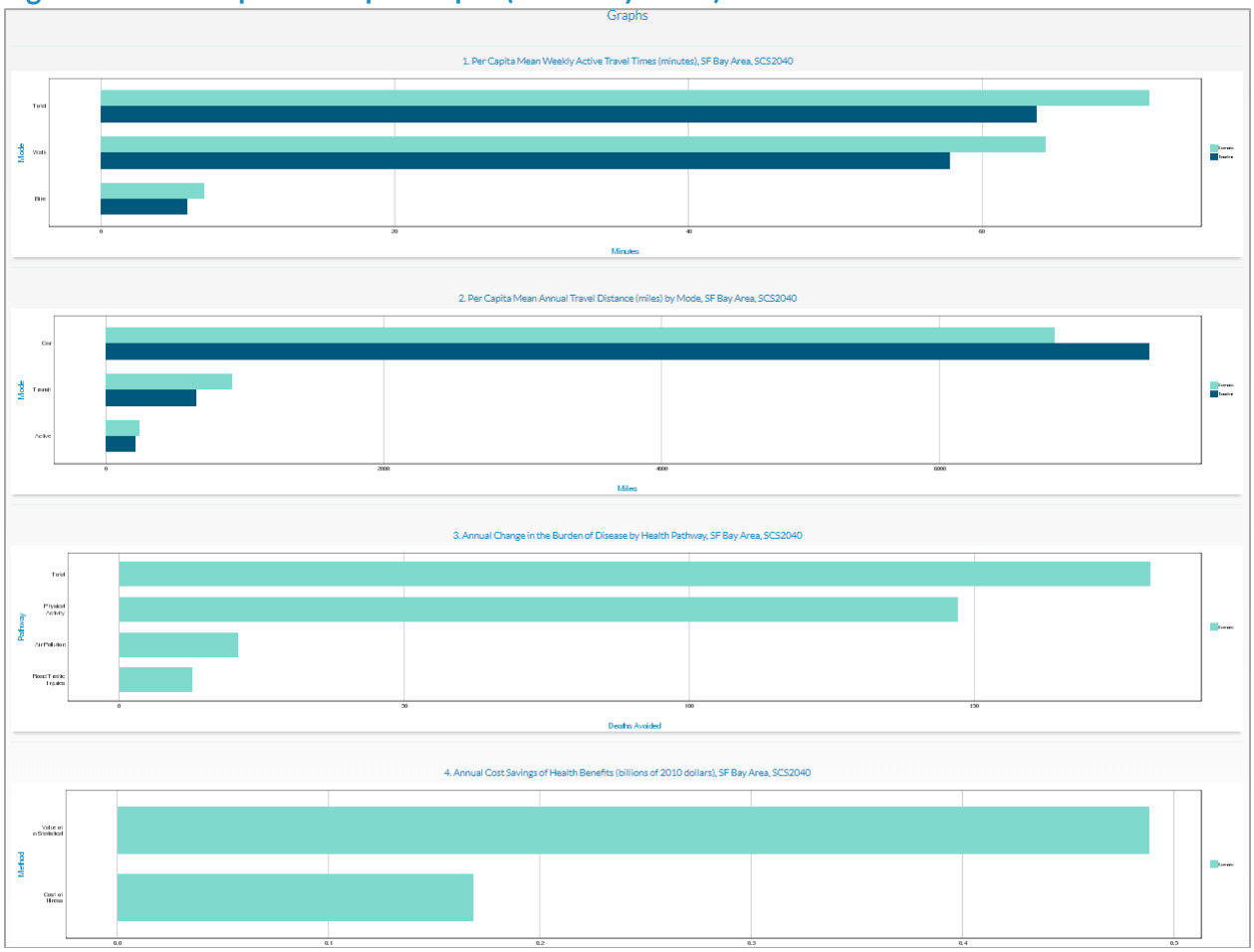
Annual Cost Savings of Health Benefits (billions of 2010 dollars), California , CARB2030

Method	Dollars
Cost of Illness	0.2
Value of a Statistical Life	0.5

Annual Car Carbon Emissions, California , CARB2030

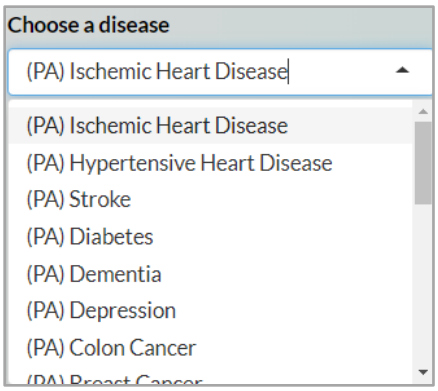
CO2.Emissions	Baseline	Scenario
Aggregate (Million Metric Tons)	15.7	14.2
Per Capita (Metric Tons)	2.2	2.0

Figure 2.18 Example of Graph Output (Summary Level)



The Summary group of tables/figures provides an overview of results that include a basic description of per capita mean active travel time, per capita mean distances traveled by mode, annual change in health outcomes and their monetized value, and annual change in carbon emissions. The Medium level of detail breaks down active travel by age and gender and travel distances by mode (car, bus, truck, rail, walk, bicycle, motorcycle). It also provides annual number of deaths, their costs, and the population attributable fraction for specific diseases. The High level of detail breaks down active travel by age, gender, and mode. Deaths, years of life lost, years living with disability, and disability life years are presented for specific diseases.

When the High level of detail is selected, another pick list of diseases and their pathways appears (at right).



Each selection generates a detailed health outcomes table/graph broken down by age and gender for deaths, YLL, YLD, DALYs and their population attributable fractions. The specific health pathway – physical activity (PA), $PM_{2.5}$ (PM), and road traffic injuries (RTI) – are indicated for each disease. Four diseases – all causes, ischemic heart disease, hypertensive heart disease, and stroke – are related to both physical activity and $PM_{2.5}$ (PA + PM). The pick list allows

users to select disease- and pathway-specific health impacts, and, for the four diseases, the combined effects of physical activity and $PM_{2.5}$.

Figure 2.19 Example of Health Outcomes by Age and Gender for a Specific Disease (Ischemic Heart Disease) and Pathway (Physical Activity)

Cause-Specific Change in Burden of Disease by Age and Sex, California , CARB2030

Disease.Injury.Classification	Pathway	Sex	Age.Group	Deaths	YLL	YLD	DALY	PAF.deaths	PAF.yll	PAF.yld	PAF.daly
Ischemic Heart Disease	PA	M	00-04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ischemic Heart Disease	PA	M	05-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ischemic Heart Disease	PA	M	15-29	0.1	3.1	0.5	3.6	0.4	0.4	0.4	0.4
Ischemic Heart Disease	PA	M	30-44	1.2	54.2	5.5	59.7	2.1	2.1	2.1	2.1
Ischemic Heart Disease	PA	M	45-59	2.3	76.9	5.8	82.7	0.5	0.5	0.5	0.5
Ischemic Heart Disease	PA	M	60-69	10.8	250.9	21.3	272.2	2.1	2.1	2.1	2.1
Ischemic Heart Disease	PA	M	70-79	1.9	28.0	2.5	30.5	0.3	0.3	0.3	0.3
Ischemic Heart Disease	PA	M	80+	4.7	30.0	2.5	32.6	0.3	0.3	0.3	0.3
Ischemic Heart Disease	PA	F	00-04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ischemic Heart Disease	PA	F	05-14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ischemic Heart Disease	PA	F	15-29	0.0	1.1	0.3	1.4	0.3	0.3	0.3	0.3
Ischemic Heart Disease	PA	F	30-44	0.1	3.3	0.7	4.0	0.5	0.5	0.5	0.5
Ischemic Heart Disease	PA	F	45-59	0.4	12.4	2.0	14.4	0.3	0.3	0.3	0.3
Ischemic Heart Disease	PA	F	60-69	0.7	16.0	2.2	18.2	0.3	0.3	0.3	0.3
Ischemic Heart Disease	PA	F	70-79	1.3	18.2	1.9	20.1	0.3	0.3	0.3	0.3
Ischemic Heart Disease	PA	F	80+	2.5	13.6	1.0	14.6	0.1	0.1	0.1	0.1
Ischemic Heart Disease	PA	Both	Total	25.9	507.7	46.3	553.9	0.4	0.7	0.6	0.7

Time and Distance Units

Active Travel Time

Users have the option of expressing per capita active travel time as a population mean or median or in units of minutes per day or minutes per week (Figure 2.20). Underlying the choice of mean or median is the observation that the distribution of active travel time in most populations is lopsided: a large percentage of the population engages in very little active travel and a small percentage are very active. This gives rise to a log-normal or humped distribution rather than a symmetrical bell shaped or normal distribution. For log normally distributed characteristics, such as active travel time, the population median (50% point of observations ordered from smallest to largest) may better represent the central tendency of the population. Means will be larger than medians.

Travel Distances

Users can express travel distances units of miles or kilometers, and the time basis for these distances can be expressed per day, per week, or per year. The choice of units were designed to

Figure 2.20 Choices for Units for Active Travel Time and Travel Distances

align with the conventions of different disciplines (urban planning, travel modeling, and health sciences).

Saving Outputs

Users have several options to save to their desktop computers the outputs that appear in the right side panel of the RunITHIM page. First is a comma separated file of the series of tables that has been selected (Summary, Medium, or High detail).

Figure 2.21 Procedures for Downloading Outputs as a CSV File

Clicking on the download button will open a dialogue box with a folder directory of your computer. Using the commands of your computer's operating system, you can save the file to a specific directory. An example of the file format is presented below.

Figure 2.22 Example of a downloaded CSV file for the Summary Level of Detail

Baseline | Scenario | Level of Detail | Geography | Evaluation Year | Today's Date | Table Title | Row Item Name | Table Values

baseline	scenario	detail_level	geography	time_period	date_generated	table	a	b	c	d	e
Baseline2010	CARB Scoping Plan (2030)	Summary	California	2010	9/19/2019	Annual Changes in Active Travel Time, Deaths, Costs, and Carbon Emissions	Item	Baseline	Scenario		
Baseline2010	CARB Scoping Plan (2030)	Summary	California	2010	9/19/2019	Annual Changes in Active Travel Time, Deaths, Costs, and Carbon Emissions	Active Travel Time (min/p/week)	40.57	180.91		
Baseline2010	CARB Scoping Plan (2030)	Summary	California	2010	9/19/2019	Annual Changes in Active Travel Time, Deaths, Costs, and Carbon Emissions	Avoided Deaths	NA	5776.72		
Baseline2010	CARB Scoping Plan (2030)	Summary	California	2010	9/19/2019	Annual Changes in Active Travel Time, Deaths, Costs, and Carbon Emissions	Health Cost Savings ($ billion 2010)	NA	6.43		
Baseline2010	CARB Scoping Plan (2030)	Summary	California	2010	9/19/2019	Annual Changes in Active Travel Time, Deaths, Costs, and Carbon Emissions	Carbon Emissions (MMTY)	94.56	76.98		
Baseline2010	CARB Scoping Plan (2030)	Summary	California	2010	9/19/2019	Per Capita Mean Weekly Active Travel Times (minutes)	Mode	Baseline	Scenario		
Baseline2010	CARB Scoping Plan (2030)	Summary	California	2010	9/19/2019	Per Capita Mean Weekly Active Travel Times (minutes)	Walk	36.95	148.21		
Baseline2010	CARB Scoping Plan (2030)	Summary	California	2010	9/19/2019	Per Capita Mean Weekly Active Travel Times (minutes)	Bike	3.63	32.70		
Baseline2010	CARB Scoping Plan (2030)	Summary	California	2010	9/19/2019	Per Capita Mean Weekly Active Travel Times (minutes)	Total	40.57	180.91		
Baseline2010	CARB Scoping Plan (2030)	Summary	California	2010	9/19/2019	Per Capita Mean Annual Travel Distance (Miles) by Mode	Mode	Baseline	Scenario		
Baseline2010	CARB Scoping Plan (2030)	Summary	California	2010	9/19/2019	Per Capita Mean Annual Travel Distance (Miles) by Mode	Active	334.44	1526.68		
Baseline2010	CARB Scoping Plan (2030)	Summary	California	2010	9/19/2019	Per Capita Mean Annual Travel Distance (Miles) by Mode	Car	10349.00	8424.96		
Baseline2010	CARB Scoping Plan (2030)	Summary	California	2010	9/19/2019	Per Capita Mean Annual Travel Distance (Miles) by Mode	Transit	181.71	624.49		
Baseline2010	CARB Scoping Plan (2030)	Summary	California	2010	9/19/2019	Per Capita Mean Annual Travel Distance (Miles) by Mode	Total (ind. Truck & Motorcycle)	11626.58	11626.58		
Baseline2010	CARB Scoping Plan (2030)	Summary	California	2010	9/19/2019	Annual Change in the Burden of Disease by Health Pathway	Pathway	PAF.Deaths	Deaths.Avoided	PAF.Dalys	Dalys.Avoided
Baseline2010	CARB Scoping Plan (2030)	Summary	California	2010	9/19/2019	Annual Change in the Burden of Disease by Health Pathway	Physical Activity	6.86	6019.13	6.64	118645.13
Baseline2010	CARB Scoping Plan (2030)	Summary	California	2010	9/19/2019	Annual Change in the Burden of Disease by Health Pathway	Air Pollution	0.02	16.96	0.02	232.66
Baseline2010	CARB Scoping Plan (2030)	Summary	California	2010	9/19/2019	Annual Change in the Burden of Disease by Health Pathway	Road Traffic Injuries	-8.58	-258.51	-8.58	-14390.29
Baseline2010	CARB Scoping Plan (2030)	Summary	California	2010	9/19/2019	Annual Change in the Burden of Disease by Health Pathway	Total	3.34	5777.59	3.06	104487.50
Baseline2010	CARB Scoping Plan (2030)	Summary	California	2010	9/19/2019	Annual Cost Savings of Health Benefits (billions of 2010 dollars)	Method	Dollars			
Baseline2010	CARB Scoping Plan (2030)	Summary	California	2010	9/19/2019	Annual Cost Savings of Health Benefits (billions of 2010 dollars)	Cost of Illness	6.43			
Baseline2010	CARB Scoping Plan (2030)	Summary	California	2010	9/19/2019	Annual Cost Savings of Health Benefits (billions of 2010 dollars)	Value of a Statistical Life	42.74			
Baseline2010	CARB Scoping Plan (2030)	Summary	California	2010	9/19/2019	Annual Car Carbon Emissions	CO2 Emissions	Baseline	Scenario		
Baseline2010	CARB Scoping Plan (2030)	Summary	California	2010	9/19/2019	Annual Car Carbon Emissions	Aggregate (Million Metric Tons)	94.56	76.98		
Baseline2010	CARB Scoping Plan (2030)	Summary	California	2010	9/19/2019	Annual Car Carbon Emissions	Per Capita (Metric Tons)	2.73	2.23		

The title of the table is given for each row of table data. "Item" is the contents of the first table column(a), and b, c, d, and e refer to successive columns. You can open the CSV table in Excel or other spreadsheet application to make further edits or format changes.

Outputs can be printed or saved to the hard drive a desktop computer. To print the current webpage, use your browser tool by selecting Print or type <Ctrl> + P. You will have the option of saving the page as a PDF or printing it as a hard copy on a printer.

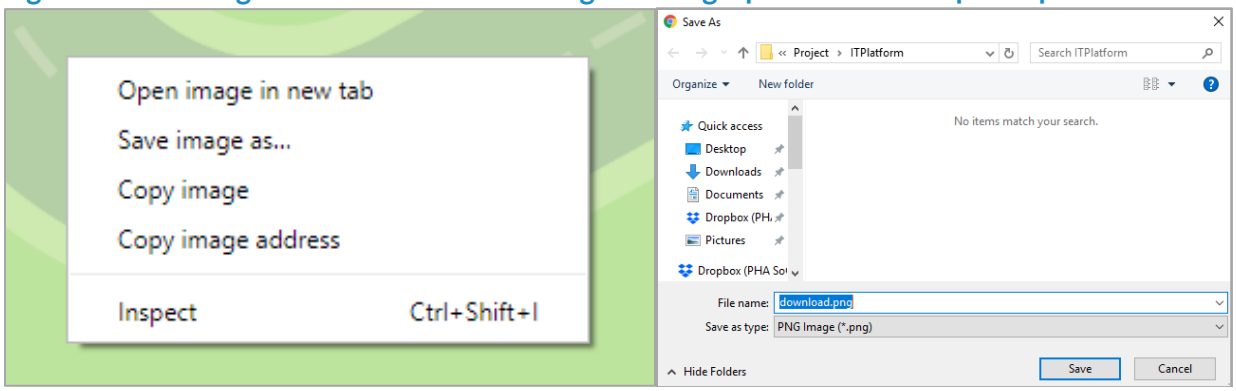
Summary Report

To save the Summary Report as editable text, highlight the icons and text of the report and then cut-and-paste the selection into a Word document.

Infographic

The infographic is downloadable as a PNG file with the default name of "download.png. Right click on the Infographic to initiate the dialogue box (left below). Select "Save image as" to open a new dialogue box (right below) that displays the file folder directory of your desktop. Navigate to the folder of your choice and save and/or rename the file.

Figure 2.23 Dialogue Boxes for Downloading the Infographic to a Desktop Computer



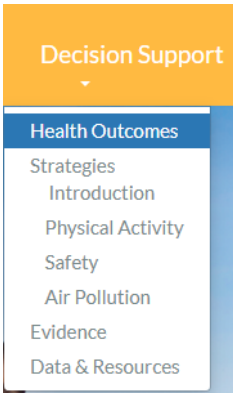
Tables

Tables can be saved as editable, formatted text by highlighting the table (title and rows and columns), and cutting-and-pasting into an Excel or Word document. HTML5 using Shiny will preserve the tabular format and the color scheme of the web-based table.

Graphs

Graphs follow the same steps as the infographic. Right click on the graph to initiate the dialogue box (left below). Select "Save image as" to open a new dialogue box (right below) that displays the file folder directory of your desktop. Navigate to the folder of your choice and save and/or rename the file. Remember to save the corresponding title.

Decision Support Pages



The Decision Support are comprised of 7 subpages that help users put the outputs of the RunITHIM page into a broader public health context and help users identify strategies to increase transportation-related physical activity, increase traffic safety, and reduce vehicle-related air pollution, carbon emissions, and miles traveled (VMT).

Health Outcomes

"Health Outcomes" is the first Decision Support page and has style elements in common with all Decision Support pages. The left side-panel has a navigation menu that allows you to rapidly access other decision support pages (Figure 2.24).

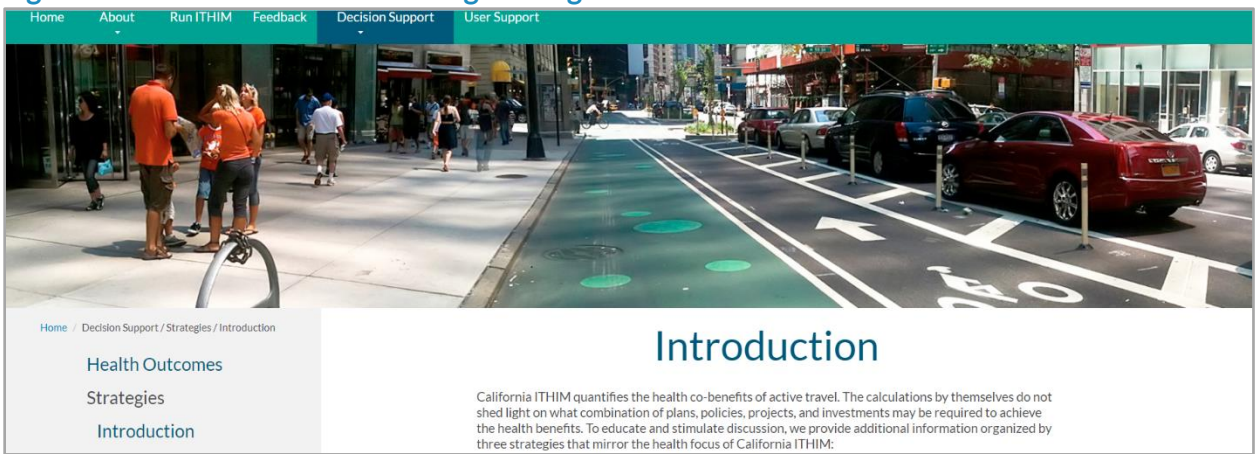
Figure 2.24 Features of the "Health Outcomes" Page

The "Health Outcomes" page has information on the prevalence and costs of chronic diseases and injuries related to lack of physical activity, air pollution, and traffic collisions.

These include the specific diseases modeled in ITHIM and other health conditions that scientific studies link to environmental hazards in the transportation system. To inform users about health equity, variation in disease and injury rates are presented by race/ethnicity, income, geography, and modes of transportation. A reference section provides links to California health statistics and scientific evidence for the health impacts and costs of physical inactivity, air pollution, and traffic injuries.

Strategies

Figure 2.25 Features of the "Strategies" Pages

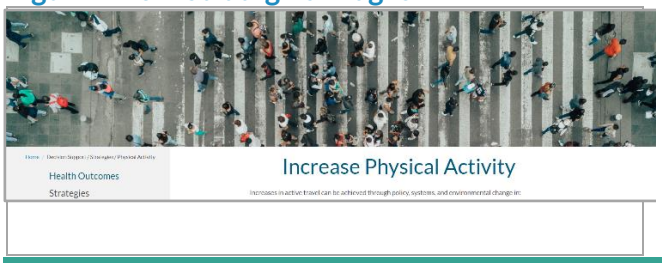


The Introduction is the first of three strategies pages, each of which corresponds to the strategies to:

1. Increase physical activity
2. Increase safety
3. Decrease air pollution, greenhouse gases, and vehicle miles traveled (VMT)

The Introduction lays out the public health framework for presenting strategies. The framework is **policy, systems, and environmental change (PSE)**. Policy change involves institutionalizing rules or procedures at the legislative or organizational level through laws, ordinances, resolutions, and regulations. Systems change involves changing rules or procedures within an organization. Environmental change is made to the physical environment that impacts community level resources and populations.

Figure 2.26 "Strategies" Pages



The Policy section of each strategy page has descriptions and links to recent California legislation and policies discussed or implemented elsewhere. The Systems sections focuses on change within systems of governmental agencies or coordination between agencies that does not require

legislative action. The Environmental section describes infrastructure investments and engineering solutions to the transportation system or built environment that promote the strategies.

Links are provided to guidelines, best practices, and exemplary programs.

Evidence

Figure 2.27 Features of the "Evidence" Page

The "Evidence" page summarizes and references the scientific evidence for the strategies of increasing physical activity through active travel, increasing safety of active travel, and decreasing air pollution, greenhouse gases, and vehicle miles traveled (VMT).

Data & Resources

The "Data & Resources" page (Figure 2.28) provide information on the following:

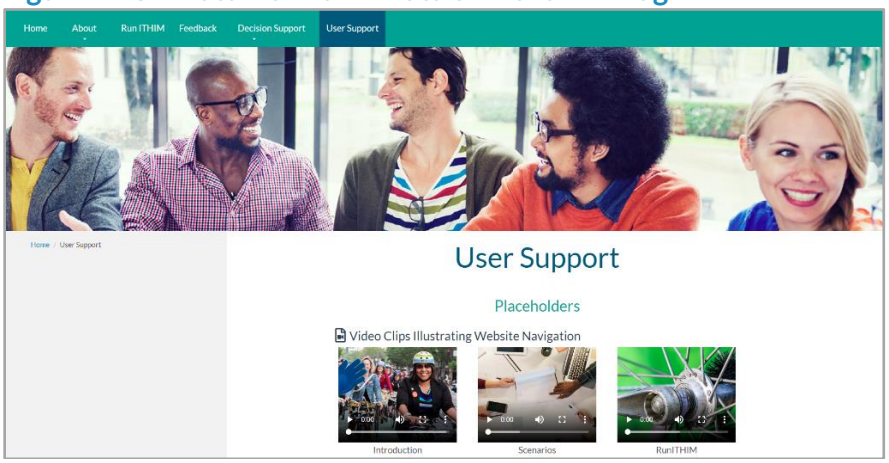
- Description of data sources used in California ITHIM
- Links to obtain a copy of the California ITHIM data files (CaliforniaITHIM_Data.zip)
- Street, bikeway, transit design best practices from national professional organizations
- Safety countermeasures from federal transportation authorities
- Neighborhood design standards from national organizations

Figure 2.28 Features of the "Data & Resource" Page

- State of California agencies responsible for transportation, safety, air pollution, and public health
- National community-based organizations with California affiliates for active travel and safety
- Programmatic approaches and materials to promote health equity in transportation systems
- Guides for physicians, nurses, and public health practitioners on climate change and health
- California indicator projects/mapping tools with transportation and health information for census tracts
- Links to international ITHIM developers and other transportation-health impact models.

User Support Page

Figure 2.28 Features of the "Data & Resource" Page



The "User Support" page provides information on how to navigate the California ITHIM website and information for software developers, and analysts who wish to deepen their knowledge of the operational details of California ITHIM. The materials include

- Short video clips introducing the website and use of the tool in the RunITHIM page
- Links to a quick navigation guide in PDF format (ITHIM_quickguide.pdf)

- Links to this User's Guide (CaliforniaITHIMUsersGuide.pdf)
- A chart book in PDF format of statewide (ITHIM_chartbook_california.pdf) and regional (ITHIM_chartbook_regions.pdf) health impacts of scenarios based on state agency goals and national physical activity recommendations
- Instructions in pdf format on how to upload scenario and equity data (ITHIM_upload.pdf)
- R code and supporting files of the California ITHIM R application
- R Code that formats outputs of travel models as inputs for California ITHIM scenarios (contributed by California MPOs)
- A glossary of acronyms used in the website and User's Manual (ITHIM_glossary.pdf).

Chapter References

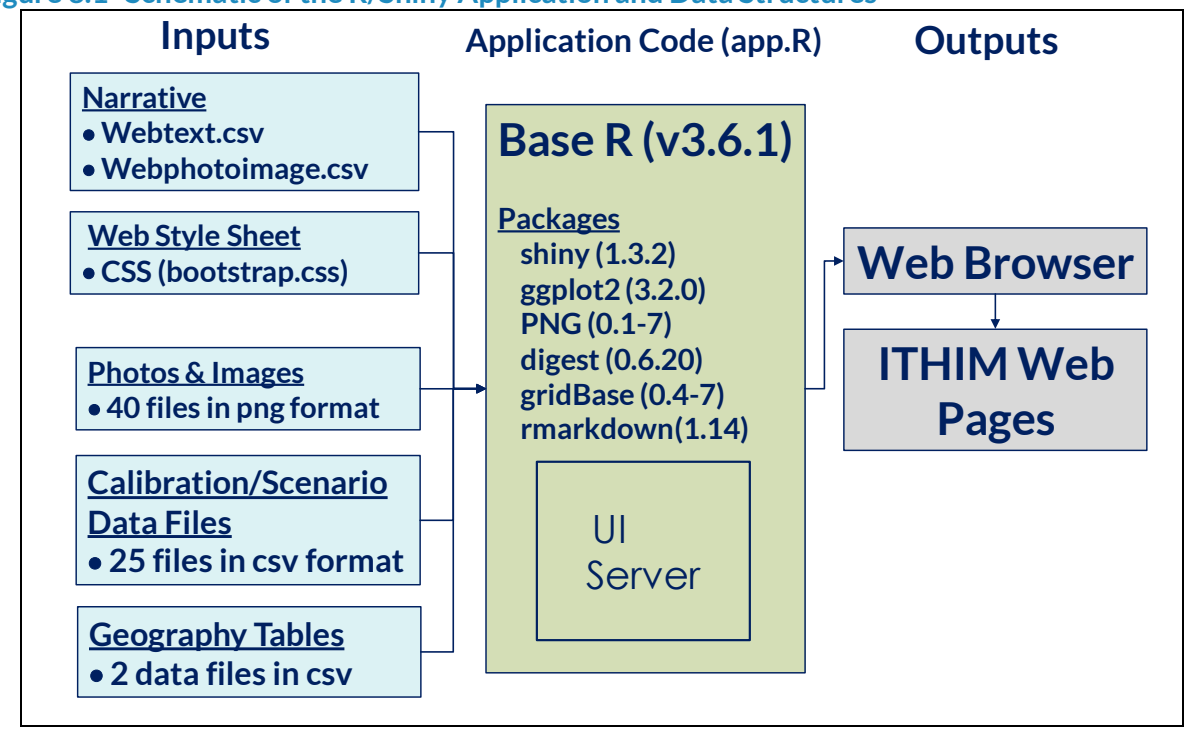
20. R Core Team. *R: A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing; 2016.http://www.R-project.org/. Accessed April 4, 2019.
21. RStudio. *Shiny R Package*. Boston, MA: RStudio; 2019.http://shiny.rstudio.com/. Accessed April 4, 2019.

Chapter 3. Programmer's Guide to California ITHIM

Schematic of Process and Data Structures

The California ITHIM R/Shiny software application combines R commands; web narrative (text) and HTML commands; photos, icons, and other images and corresponding text for accessibility text readers; a cascading style sheet (CSS) based on the Bootswatch Flatly template; [22, 23] and calibration and scenario data files (Figure 3.1). The application was initially developed on desktop computers using RStudio, [21] which is an interactive development environment (IDE).

Figure 3.1 Schematic of the R/Shiny Application and Data Structures



Input Files

There are five categories of inputs to the R application (app.R), which generates the HTML interpreted by the web browser on your desktop/laptop computer and displays web pages.

Text and Image Management

The "webtext.csv" file has web page narrative and formatting commands called HTML tags and occasional CSS styling instructions. The file is a look-up table linked to the R application by the unique entries in column 1 called "Element". When an R command is executed, the text of the "Contents" (column 2) populates the web page. This approach adds flexibility to web page maintenance, so that changes to the wording of web pages can be done without knowledge of R programming or the need to modify the R codes itself (hard coding). There is an additional column for notes, mostly pertaining to HTML representation of special characters (©, no-break spaces - , Greek letters, etc.). Webstext.csv and its layout are presented below.

Table 3.1 Sample of Text from "webstext.csv" File

Element	Content
hp.versiontext	DRAFT FOR DISCUSSION ONLY - Website Under Construction - UC Davis - September 17, 2019
hp.bannertext	Transportation Planning for Health, Equity, and Climate Change
hp.bannercaption	Replacing short car trips with walking, cycling, and transit increases physical activity and cuts air pollution and climate-warming emissions
hp.bannersubcaption	Every year, more than 30,000 Californians die prematurely from traffic injuries and chronic diseases linked to physical inactivity and air pollution. Learn about active travel health benefits, harms, and cost savings in California transportation plans and for goals in your own community.
hp.leftbutton	What is ITHIM?
hp.centerbutton	How do I use ITHIM?
hp.rightbutton	Start Using ITHIM
hp.leftsubbutton	Learn More
hp.centersubbutton	See Instructions
hp.rightsubbutton	Go Now
hp.pithyquote	"The idea that we can cure ourselves and the planet by simply walking or riding a bicycle is both obvious and daunting given our current transportation system. ITHIM makes the case that active travel has a prominent role in solving the twin crises of chronic disease and climate change."
hp.pithyquoteauthor	UC Davis ITHIM Development Team
hp.gallerytitle	A Sample of ITHIM Results from Scientific Publications and Reports
hp.galleryintro	Since 2009, ITHIM has played a role in elucidating the health co-benefits of active travel as a strategy to reduce greenhouse gas emissions. The model has been used by California's regional transportation planning agencies, the California Air Resources Board, Department of Public Health, and local health departments to evaluate their strategic goals.
hp.galleryfig1	<a href = "https://doi.org/10.1016/S0140-6736(09)61714-1"
hp.galleryfigcap1	ITHIM models transportation-related physical activity, air pollution, and traffic injuries
hp.galleryfig2	<a href = "https://data.chhs.ca.gov/dataset/adults-meeting-physical-activity-guidelines-lghc-indicator-16"
hp.galleryfigcap2	Many Californians are not physically active, and few get physical activity from active travel
hp.galleryfig3	<a href = "https://www.ncbi.nlm.nih.gov/pubmed/25900805"
hp.galleryfigcap3	Active transport reduces chronic disease, but may increase injuries
hp.galleryfig4	<a href = "https://doi.org/10.1016/j.jth.2017.04.011"
hp.galleryfigcap4	Health benefits follow increases in active transport

Table 3.2 File Layout of the "webtext.csv" file

Variable	Definition	Coding levels
Element	Unique identifier for an element on a web page	First two or three characters identify the web page that the element is part of: hp = Home Page ap = About Page > Introduction in = About Page > Instructions sc = About Page > Scenarios geo = About Page > Geographies tm = About Page > Time Periods me = About Page >Methods rp = RunITHIM tt = tool tip on Run Pages ds = Decision Support ds.ho = Decision Support > Health Outcomes ds.st = Decision Support > Strategies ds.ev = Decision Support > Evidence ds.dr = Decision Support > Data & Resources us = User Support
Contents	Text and HTML tags for the content of a web page	= begin and end of paragraph text>= hypertext linkage </u> = begin/end of unordered list = begin/end of ordered list = begin/end of line entry in unordered list = begin/end of bold text = begin/end of superscripted character - begin/end of subscripted character <u></u> = begin/end of underline =apply HTML command to items within the span tags <th></th> = begin/end of a table column headers <tr></tr> =beginning/end of table row <td></td> = beginning/end of data points of a table row = beginning/end of third level header text = beginning/end of fourth level header text
Notes	Special characters or instructions for HTML or CSS codes	&#215 = multiply sign &#181 = micro symbol = no break space &copy = copyright symbol

The "webphotoimage.csv" file is also a look-up table linked to the R application by the unique entries in column 1 called "Element". When an R command is executed, the photo or image file name listed in "Filename" (column 2) populates the web page. The contents of "Alttext" are also incorporated into the website so that text readers can provide visually impaired users with a description of the image. This approach adds flexibility to web page maintenance, so that photographs can be easily exchanged without knowledge of R programming.

21. RStudio. *Shiny R Package*. Boston, MA: RStudio; 2019.http://shiny.rstudio.com/. Accessed April 4, 2019.
22. Park T. *Bootswatch: Free themes for Bootstrap, Flatly*; 2016.https://bootswatch.com/flatly/. Accessed April 8, 2019.
23. Park T. *Introducing Bootswatch*; 2012.https://thomaspark.co/2012/02/introducing-bootswatch/. Accessed April 8, 2019.

Table 3.3 Sample of Data from "webphotoimage.csv" File

Element	Filename	Alttext	Title
hp.wordmark	ITHIMWordmark_725by115.png	ITHIM wordmark	ITHIM wordmark
hp.banner	background-image: url('home_page_banner2000by750.png');	Smiling bicycle riders	Smiling bicycle riders
hp.gallery1	ITHIMbubble375by250.png	ITHIM pathway diagram	ITHIM pathway diagram
hp.gallery2	figure375by250.png	Line graph of active travel time	Line graph of active travel time
hp.gallery3	ITHIMPAFDx375by250.png	Table of change in burden of disease and road traffic injuries	Table of change in burden of disease and road traffic injuries
hp.gallery4	Walk_BikeDALYs-min375by250.png	Line graph of death as a function of active travel	Line graph of death as a function of active travel
hp.gallery5	EquityPies375by250.png	Pie charts of California regions by relative and absolute physical activity goals	Pie charts of California regions by relative and absolute physical activity goals
hp.gallery6	ITHIM_quote375by250.png	Quote from journal article	Quote from journal article
hp.sponsor	CARBlogo250by200.png	California Air Resources Board	California Air Resources Board
hp.sponsor2	CDPH_logo300by200.png	California Department of Public Health	California Department of Public Health
ap.intro	background-image: url('WalkingHollywood2000by400.png');	Pedestrians in crosswalk, Hollywood Blvd.	Pedestrians in crosswalk, Hollywood Blvd.
ap.ucdlogo	UCDlogo400by150.png	UCD Logo	USC Logo
ap.instruct	background-image: url('SchoolChildrenCrossingStreet2000by400.png');	Crossing guard with school children	Crossing guard with school children
ap.scenbanner	background-image: url('Scenarios2000by400.png');	Four planners discussing scenarios	Four planners discussing scenarios
ap.scenario1	Baseline2010_200by200.png	Baseline 2010	Baseline 2010
ap.scenario2	CARBScopingPlan200by200.png	California Air Resources Board	California Air Resources Board
ap.scenario3	Caltrans2020SMP200by200.png	Caltrans	Caltrans
ap.scenario4	SCS2040_200by200.png	Sustainable Community Strategies	Sustainable Community Strategies
ap.scenario5	USSG200by200.png	US Surgeon General	US Surgeon General
ap.scenario6	BaselineMultiples200by200.png	Multiples of baseline	Multiples of baseline
ap.scenario7	FixedTime200by200.png	Fix amount of time	Fixed amount of time

The "webphotoimage.csv" file follows the same convention as the "Element" field in the "webtetx.csv" file regarding the first 2 or 3 letters that reference the web page of photo or image. The file also has a column "Size", which provides the dimensions in pixels of the image.

Web Style Sheet

Modern web programming uses HTML tags in conjunction with a styling commands that are consolidated in a text file called a cascading style sheet (CSS). California ITHIM uses a free and open-source CSS template called Bootswatch "Flatly" (https://bootswatch.com/flatly/), which is based on the Bootstrap family of style sheets. Bootstrap design templates encompass typography, forms, buttons, navigation and other interface components. The Flatly style sheet (148 KB, 7100 lines) was modified to incorporate the Lato family of fonts and the color palette in the CARB website style guidelines.

Table 3.3 Selected Style Elements in Bootswatch.css File

Style Element	HTML Tag	CSS Element	Pixels
First header level	h1	color: #0F5A7C (dark blue)	32
Second header level	h2	color: #36A393 (turquoise)	24
Third header level	h3	color: #1F8BBF (light blue)	18
Paragraph	p	color: #4D4D4F (dark grey)	16
Table heading background	th	color: #36A393 (turquoise)	
Table row color	tr	color: #deeaf6 (pale blue)	

Comments were inserted in the "bootstrap.css" file to indicate where changes were made to the original CSS. For example, changes in the style for tables was documented by the sequence below.

```
/* Change Table header background CARB green */
th {
    background-color: #36A393;
    color: white;
    border: 1px solid white;
     padding: 0;
}

/* Light blue zebra alternating rows */
tr:nth-child(even) {background-color: #deeaf6;
}
```

Style elements unique to California ITHIM appear at the end of the bootstrap.css file (lines 7238 - 7581).

Calibration/Scenario

California has 21 data files in CSV format that are used to calibrate the model for baseline conditions in 2010 and 3 files for travel patterns of three scenarios: Short Trips, US Surgeon General Physical Activity Recommendations (USSG), and the Sustainable Communities Strategies, 2040 (SACS 2040). The names of the files are presented in Table 3.4 and their layout is presented in Table 3.5.

Table 3.4 Calibration and Scenario data File Names, Descriptions, and Primary Source by Class of Information, California ITHIM

Category	File Name	Description	Primary Source
Burden of Disease	CalBurdenDisease2010.csv	Age-sex-cause-region specific deaths, yll, yld, dalys	Institute for Health Metrics and Evaluation
Burden of Disease	APC_Disease_Rates.csv	Age-sex-cause specific annual change in mortality rates	Canudas et al, 2017
Burden of Disease	DiseaseRiskAdjuster.csv	Age-sex-cause specific adjustment factor to population subgroup (equity analysis)	user-defined (e.g. race/ethnicity, income, etc.)
Car CO2	CO2g_mi.csv	Region-specific grams of CO2 per car mile traveled	ARB-EMFAC14
Costs	COI2010USD.csv	Cause-specific per capita costs of illness	MEPS, NCI, medical specialty societies
Exposure	ATmean_min_week_age_sex_baseline.csv	Age-sex-region-specific minutes of walking and cycling/p/y by mode	CHTS2012
Exposure	bike_walk_cv.csv	Region-specific coefficient of variation for mean active travel (mi/p/y)	CHIS2009, NM processed
Exposure	METminWalk_Bike.csv	Age-sex-mode (walk/bike) specific MET weights for active travel	James Woodcock, 2011
Exposure	nonTravelMETS.csv	Age-sex-quintile specific min/p/w of non-travel METs	CHIS 2009, SAS program Item4_CHIS2009_PA_Quintiles_SD8-30-13Confidential.sas
Exposure	default_narratives_2019_07_10.csv	Region-specific travel miles/p/y by mode for 2010 baseline and built-in scenarios: Sustainable Community Strategies. Short trips, US Surgeon General (USSG)	CHTS2012, MPO TDMs; For SCS, AT MPO EIR relative increase from baseline, For USSG, baseline motorized modes + 75 med min bike/walk converted to mean and then 3 and 12 mph speed; For Short Trips and USSG, increase in active travel is offset by reduction in car miles maintaining baseline occupancy .
Exposure	Baseline_distance_by_facility_type.csv	Region-specific percentage of VMT by mode and facility type	MPO and California Statewide travel demand models

Category	File Name	Description	Primary Source
Exposure	PM25CARB2010_2050.csv	Region-specific change in PM2.5 with car emissions as a function of change in car VMT, 2010 to 2050 in 5 year intervals	EMFAC, Air shed models
Exposure	WalkBikeTransitRatios.csv	Region and mode (bike/walk)-specific ratio of transit travel time (min/p/y)	CHTS 2012
Exposure	Bus_occupancy.csv	Region-specific bus occupancy	MPOs, CHTS2012
Parameters	ParameterDefaults.csv	Default constants (e.g., walk, speed, bike speed, VSL, etc.)	Constants for travel, health outcomes, costs
Population	age_sex_region2010.csv	Age-sex-region-population proportions for baseline year 2010	USCensus_2010_SF1_QTP1
Population	age_sex_region_county2010-2050.csv	Age-sex-county population projections in 5 calendar year bands from 2015-2050	USCensus_2010_SF1_QTP1, CaDoF_2015-2050 (P3 file)
Risk	PA_RR.csv	Disease-specific RR per METhr-wk	JamesWoodcock2010
Risk	PM25_RR.csv	Disease-specific RR per $\mu g/m^3$ of PM2.5	CARB recommended value for cardio-pulmonary disease, Woodcock 2009 for lung cancer, acute respiratory illness in children
Risk	rti_baseline.csv	Region-severity-facility specific RTIs by striking and victim mode for baseline year	SWITRS, 2011-2016

Table 3.5 Variable Names, Definitions, and Coding Levels of Calibration and Scenario Data Files, California ITHIM

File Name	Variable Name	Definition	Code Levels
CalBurdenDisease2010.csv	Region	California and 5 MPO regions	California; SF Bay Area; San Joaquin Valley; Sacramento Area; Southern California; San Diego County
	Year	Year of death	
	Cause	Cause of death	Ischemic Heart Disease, Stroke, Hypertensive Heart Disease, Diabetes, Breast Cancer, Colon Cancer, Dementia, Depression, Inflammatory Heart Disease, Lung Cancer, Respiratory diseases, Acute resp infections, Road Traffic Injuries
	Sex	Gender	1=M, 2=F
	Age	Age group identifier	0=0-4, 5=5-14, 15=15-29, 30=30-49, 50=50-59, 60=60-69, 70=70-70, 80=80+
	pop	Population	DOF
	deaths	Number of deaths	Global Burden of Disease for US adjusted to mortality ratio of region to US for age-sex deaths >10
	yll	Years of life lost	Global Burden of Disease for US adjusted to mortality ratio of region to US for age-sex deaths >10
	yld	Years living with disability	Global Burden of Disease for US adjusted to mortality ratio of region to US for age-sex deaths >10
	daly	Disability-adjusted life years	Global Burden of Disease for US adjusted to mortality ratio of region to US for age-sex deaths >10
APC_Disease_Rates.csv	Cause	Specific cause of disease	Ischemic Heart Disease, Stroke, Hypertensive Heart Disease, Inflammatory Heart Disease, Lung Cancer, Respiratory diseases, Acute resp infections
	Sex	Gender	1=M, 2=F
	Age	Age group identifier	0=0-4, 5=5-14, 15=15-29, 30=30-49, 50=50-59, 60=60-69, 70=70-70, 80=80+
	APC	Annual percent change in mortality rate	0 to 100

Table 3.5 Variable Names, Definitions, and Coding Levels of Calibration and Scenario Data Files, California ITHIM (cont'd)

File Name	Variable Name	Definition	Code Levels
DiseaseRiskAdjuster.csv	Region	Name of region (based on MPOs)	California; SF Bay Area; San Joaquin Valley; Sacramento Area; Southern California; San Diego County
	Cause	Cause of death	Ischemic Heart Disease, Stroke, Hypertensive Heart Disease, Diabetes, Breast Cancer, Colon Cancer, Dementia, Depression, Inflammatory Heart Disease, Lung Cancer, Respiratory diseases, Acute resp infections, Road Traffic Injuries
	Sex	Gender	1=M, 2=F
	Age	Age group identifier	0=0-4, 5=5-14, 15=15-29, 30=30-49, 50=50-59, 60=60-69, 70=70-70, 80=80+
	Rradj	Relative risk adjustment for co-variate	1 for deaths < 10
CO2_gmi.csv	Region	California and 5 MPO regions	California; SF Bay Area; San Joaquin Valley; Sacramento Area; Southern California; San Diego County
	Year	Year of Projection	2010 and 5 year intervals to 2050
	CO2g_mi	Grams of CO2 emitted per mile of car travel	Averaged over gas, diesel, and electric cars and light trucks
COI2010USD.csv	Cause	Specific cause of disease	Ischemic Heart Disease, Stroke, Hypertensive Heart Disease, Diabetes, Breast Cancer, Colon Cancer, Dementia, Depression, Inflammatory Heart Disease, Lung Cancer, Respiratory diseases, Acute resp infections, Road Traffic Injuries
	Specific cause	Cause mentioned in cost literature	Heart Disease, Diabetes, Breast Cancer, Colon Cancer, Dementia, Depression, Lung Cancer, Asthma and COPDs, Road Traffic Injuries
	USCost2010	National cost in constant 2010 USD	
	PerCapita2010USD	Cost per capita in constant 2010 USD	

Table 3.5 Variable Names, Definitions, and Coding Levels of Calibration and Scenario Data Files, California ITHIM (cont'd)

File Name	Variable Name	Definition	Code Levels
ATmean_min_week_age_sex_baseline.csv	Region	California and 5 MPO regions	California; SF Bay Area; San Joaquin Valley; Sacramento Area; Southern California; San Diego County
	Sex	Gender of traveler	1=M, 2=F, Both=Both
	Age	Age group identifier	0=0-4, 5=5-14, 15=15-29, 30=30-49, 50=50-59, 60=60-69, 70=70-70, 80=80+, Total
	Mode	Active mode of travel	Walk, Bike
	Baseline	Mean minutes/person/week of active travel at baseline	CHTS2012 mean distance/p/d converted to times using 3 mph average for walking and 12 mph for cycling
	Source	Source(s) of data	CHTS, 2012, except Sacramento Area, NHTS, 2009
ParameterDefaults	VariableName	Variable name of parameter	Walkspeed, Bikespeed, SiN, PAChronicBeta, PAAllCauseBeta, Nqtiles, VSL
	Definition	Definition of parameter	
	Default	Default value of parameter	3,12,0.5,0.5,0.25,5, 9800000
WalkBikeTransitRatios.csv	Region	California and 5 MPO regions	California; SF Bay Area; San Joaquin Valley; Sacramento Area; Southern California; San Diego County
	BikeTRatio	Ratio of Bike to Transit minutes	
	WalkTRatio	Ratio of Walk to Transit minutes	
	TransitMin	Baseline Transit Minutes per week	

Table 3.5 Variable Names, Definitions, and Coding Levels of Calibration and Scenario Data Files, California ITHIM (cont'd)

File Name	Variable Name	Definition	Code Levels
bike_walk_cv.csv	Region	California and 5 MPO regions	California; SF Bay Area; San Joaquin Valley; Sacramento Area; Southern California; San Diego County
	CV	Coefficient of variation of active travel time	CHIS, 2009 via SAS program Item4_CHIS2009_PA_Quintiles_SD8-30-13Confidential.sas
METminWalk_Bike.csv	Sex	Gender of traveler	1=M, 2=F, Both=Both
	Age	Age group identifier	0=0-4, 5=5-14, 15=15-29, 30=30-49, 50=50-59, 60=60-69, 70=70-70, 80=80+, Total
	METminWalk	Age-sex adjusted METS for walking	Average velocity of 3 mph, Woodcock age-sex ratios from Europe, and Ainsworth regression relationships with 2.5 minimum
	METminBike	Age-sex adjusted METS for cycling	Constant of 6 METS (no age-sex variation)
nonTravel_METS.csv	Region	California and 5 MPO regions	California; SF Bay Area; San Joaquin Valley; Sacramento Area; Southern California; San Diego County
	Sex	Gender of traveler	1=M, 2=F
	Age	Age group identifier	0=0-4, 5=5-14, 15=15-29, 30=30-49, 50=50-59, 60=60-69, 70=70-70, 80=80+
	q1	1st quintile of non-travel METS	0 - 75
	q2	2nd quintile of non-travel METS	0 - 75
	q3	3rd quintile of non-travel METS	0 - 75
	q4	4th quintile of non-travel METS	0 - 75
	q5	5th quintile of non-travel METS	0 - 75

Table 3.5 Variable Names, Definitions, and Coding Levels of Calibration ND Scenario Data Files, California ITHIM (cont'd)

File Name	Variable Name	Definition	Code Levels
default_narratives_2019_07_10.csv	Region	California and 5 MPO regions	California; SF Bay Area; San Joaquin Valley; Sacramento Area; Southern California; San Diego County
	Item_Name	Description of item	Distances (miles/person/year)
	Scenario_ID	2010 Baseline and built-in scenario names	Baseline2010, Replacing Short Car Trips with Active Travel, Sustainable Communities Strategies (2040), U. S. Surgeon General Recommendation
	Mode	Travel mode	Walk, Bike, CarDriver, CarPassenger, Bus, Rail, Motorcycle, Truck
	Baseline	Per capita mean miles/p/yr	TBD edit checks specific to mode
PA_RR.csv	Cause	Specific cause of disease	Ischemic Heart Disease, Diabetes, Breast Cancer, Colon Cancer, Dementia, Depression, Stroke, Hypertensive Heart Disease, All causes
	Sex	Gender	1=M, 2=F
	Age	Age group identifier	0=0-4, 5=5-14, 15=15-29, 30=30-49, 50=50-59, 60=60-69, 70=70-70, 80=80+
	RR	Change in RR per MET	0.89 - 0.99999
PM25_RR.csv	Cause	Specific cause of disease	Ischemic Heart Disease, Stroke, Hypertensive Heart Disease, Inflammatory Heart Disease, Lung Cancer, Respiratory diseases, Acute resp infections
	coefficient	ln(RR per μg/m3 PM2.5)	CVD, 0.01293; Lung Cancer, 0.013102826; respiratory disease, 0.01293; Acute resp infections, 0.009758033

Table 3.5 Variable Names, Definitions, and Coding Levels of Calibration and Scenario Data Files, California ITHIM (cont'd)

File Name	Variable Name	Definition	Code Levels
PM25CARB2010_2050.csv	Region	California and 5 MPO regions	California; SF Bay Area; San Joaquin Valley; Sacramento Area; Southern California; San Diego County
	pm25	Population weighted annual average PM2.5 levels, background, 2010	5-25
	slope	change in PM2.5/change car VMT	
	intercept	intercept of PM2.5/car VMT relationship	
pop_age_sex_region2010	Region	California and 5 MPO regions	California; SF Bay Area; San Joaquin Valley; Sacramento Area; Southern California; San Diego County
	Sex	Gender	1=M, 2=F, Both
	Age	Age group identifier	0=0-4, 5=5-14, 15=15-29, 30=30-49, 50=50-59, 60=60-69, 70=70-70, 80=80+, Total
	Population	Population count in 2010	
	Percent	Percent of age-sex population	0 to 1

Table 3.5 Variable Names, Definitions, and Coding Levels of Calibration ND Scenario Data Files, California ITHIM (cont'd)

File Name	Variable Name	Definition	Code Levels
pop_age_sex_region_county2010-2050	Geography	Region name or county within region	See code list
	Region	Name of region (based on MPOs)	California; SF Bay Area; San Joaquin Valley; Sacramento Area; Southern California; San Diego County
	Sex	Gender	1=M, 2=F
	Age	Age group identifier	0=0-4, 5=5-14, 15=15-29, 30=30-49, 50=50-59, 60=60-69, 70=70-70, 80=80+
	Year	Year of estimate	2010, and 5-year annual average for 2015-2019, 2020-2024, 2025-2029,2030-2034,2035-2039,2040-2044,2045-2049,2050-2054
	Population	Population estimate	5-year annual average population based on Cal Dept. of Finance Projections
Baseline_distance_by_facility_type.csv	Region	California and 5 MPO regions	California; SF Bay Area; San Joaquin Valley; Sacramento Area; Southern California; San Diego County
	Mode	Travel mode	Walk, Bike, Ca, Bus, Motorcycle, Truck
	local_pct_b	Percent of travel on local roads	0 to 1
	art_pct_b	Percent of travel on arterials	0 to 1
	hwyl_pct_b	Percent of travel on highways	0 to 1

Table 3.5 Variable Names, Definitions, and Coding Levels of Calibration and Scenario Data Files, California ITHIM (cont'd)

File Name	Variable Name	Definition	Code Levels
rti_baseline.csv	Region	California and 5 MPO regions	California; SF Bay Area; San Joaquin Valley; Sacramento Area; Southern California; San Diego County
	Severity	Severity of injury	Fatal, Serious
	Roadway	Roadway type	Local, Arterial, Highway
	VictimMode	Mode of victim	walk, bike, car, bus, rail, motorcycle, truck
	walk	Number of injuries, walk striking mode	Non-negative or 0
	bike	Number of injuries, bike striking mode	Non-negative or 0
	bus	Number of injuries, bus striking mode	Non-negative or 0
	car	Number of injuries, car striking mode	Non-negative or 0
	truck	Number of injuries, truck striking mode	Non-negative or 0
	motorcycle	Number of injuries, motorcycle striking mode	Non-negative or 0
	NOV	No other vehicle involved in collision	Non-negative or 0
bus_occupancy.csv	Region	California and 5 MPO regions	California; SF Bay Area; San Joaquin Valley; Sacramento Area; Southern California; San Diego County
	Occupancy	Occupancy (PMT/VMT)	Non-negative or 0

Of note, the 'default_narratives.csv' file contains travel distances by mode for the baseline 2010 and scenario distances by mode for the Sustainable Communities Strategies (2030), Short Trips, and U.S. Surgeon General scenarios.

Geographies

The About > Geographies page incorporates data from two tables of counties and regions (counties1col.csv, regions.csv).

Meta-Data Dictionary and Data Files

File names (Table 3.4), variables within each file, and definitions and coding levels of each variable (Table 3.5) were presented in previous pages.

Default Values

Table 3.6 presents the default values in the file 'ParameterDefaults.csv', which are constants used in calculating distances/times, population attributable fractions for physical-activity related diseases, the value of a statistic life, safety in numbers, and other inputs.

Table 3.6 Default Values for Key parameters of California ITHIM

Variable Name	Definition	Default Values
Walkspeed	Average walking speed in miles/hour	3
Bikespeed	Average bicycling speed in miles/hour	12
SiN	Safety in Numbers coefficient	0.5
PAChronicBeta	Slope of the dose-response function between physical activity and chronic diseases, exclusive of all causes	0.5
PAAllCauseBeta	Slope of the dose-response function between physical activity and all-causes mortality	0.25
NQtiles	Number of quantiles of modeled physical activity distribution	5
VSL	Value of a Statistical Life in dollars, 2010	9800000
LCD_VMT	Percent reduction in VMT/emissions in Low Carbon Driving Scenario from 2010 baseline by 2045	33.5

California ITHIM uses walk speed and bike speed to determine active travel times. Mean active travel time was derived by dividing mean distances for walking and cycling by estimated average speed. Active travel distances were calculated from origin-destination data points (in the California Household Travel Survey) linked by an assumed Google Maps route by mode. Self-reported travel times for walking and cycling are reported by survey respondents, but they regularly spike at times ending in 0 or 5, suggesting a rounding up digit bias. Walk speeds and bike speeds based on self-reported travel times and distances often leads to unrealistically low travel speeds.

Safety in numbers refers to the observation that the rate of bicycle and pedestrian injuries

appears to follow a function of bicycle and pedestrian mode share – the higher the mode share the lower the rate of injuries.[24] The function follows an inverse power relationship: injuries = mode share^n, where n is 0.5.

'PAChronicBeta' describes the functional form of the physical activity-disease dose response relationship for specific causes modeled in California ITHIM.[6] This follows from the observation that risk reduction is sharpest at the low dose end of the dose-response curve (i.e. a 5 minute increase in physical activity will have a bigger population health impact for the population with low levels of physical activity than the population with already with high levels. 'PAAllCauseBeta' describes the same phenomenon for 'PAChronicBeta', but for all causes of disease combined, where this effect is stronger.

The active travel time distribution is modeled in quintiles by default (NQtiles, 5). The value of a statistical life is based on US. EPA values ($7.4 in 2006 USD and $9.6 million in 2010 USD).[25]

The amount of carbon reductions in the Low Carbon Driving scenario is based on projections of Lutsey[26], who estimated a 33.5% reduction in carbon emissions from a 2000 baseline by 2045 due to electrification of the auto fleet and adoption of low carbon fuels. He projected an additional 16% reduction from other engineering improvements (drive train, accessories, etc.).

California ITHIM Application (app.R)

Directory and File Structure for California

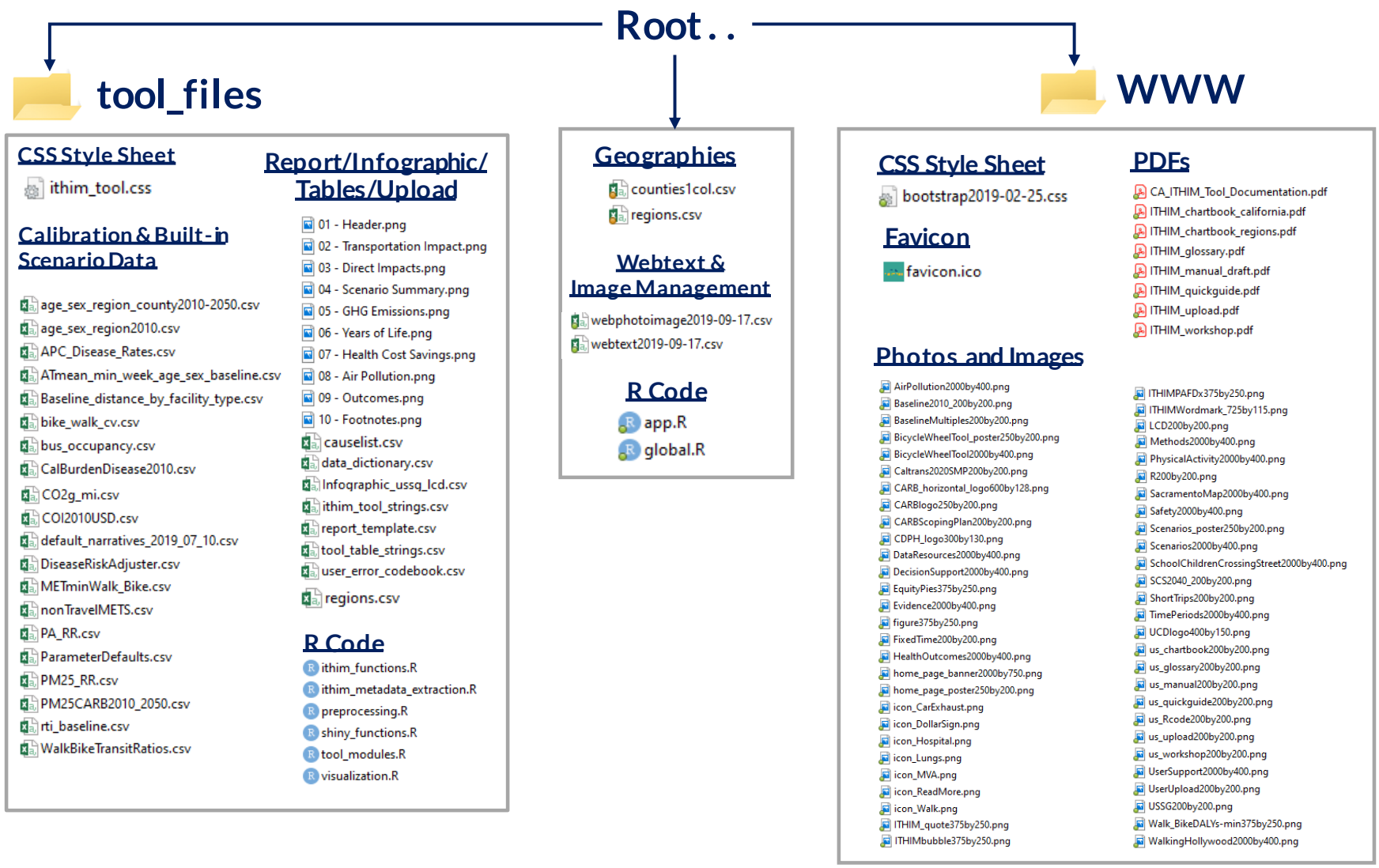
R applications follow several file and folder naming conventions (Figure 3.2). The application itself must be named "app.R", and be located in a root file directory (folder). The app.R file can be accessed from the Github repository[27] and uses R Markdown for documentation. File directories must be created ahead of time and can then be referenced within the R application. In California ITHIM, several other files are located in the root directory, including the files to manage web text and images and data for tables on the About > Geographies page. An R default directory called "www" is the location of the CSS style sheet, the favicon for the website title tab, pdfs of documents stored at the website, and photos and image files. Video tutorial files are hosted by CARB at its YouTube site (https://www.youtube.com/watch?v=sFsNd3yQo5M&feature = youtu.be). Calibration and scenario data are stored in a separate directory called "tool_files."

In addition to the base R program (version 3.6.1), California ITHIM utilizes several packages that are listed below with their function.

Table 3.7 R Packages Used in California ITHIM

Package Name (version)	Function
Shiny (1.3.2)	Generates HTML for website presentation
ggplot2 (3.2.0)	Grammar of graphic for display of bar and line charts
png (0. 1-7)	Reads and writes png images (for infographic)
Digest (0.6.20)	Creates compact hash digests of R objects (data integrity checks)
grid (0.4-7)	Integrates base and grid graphics (display of tables/graphs)
Rmarkdown (1.14)	Creates dynamic documents for R (documentation of R code)

Figure 3.2 Directory Structure and File Locations



Schematic Input-Output Diagram of California ITHIM

An overview of the functional inputs and outputs of California ITHIM are presented in Figure 3.3. The inputs include calibration and built in scenario data and constants, which the analytic engine converts to outputs covering changes in the burden of disease by pathway (physical activity, PM2.5, road traffic injuries), monetized costs of the health outcomes, and CO_2 emissions of cars. Figure 3.4 describes the basic program flow and the major functions of the analytic engine. Table 3.7 gives the mathematical formulae for the key functions.

Overview of the Structure of the R Application (app.R)

The development of the California R/Shiny application was guided by the following:

- Programming with basic R and the Shiny package with other packages used sparingly and only when to achieve a specific functional requirement of the application

- "Top-down" programming of functional components, which were broken down into a sequence of steps. This contrasts with more advanced programming techniques such as object-oriented programming.

Thus, the guiding philosophy of application development emphasized a reduction in complexity commensurate with skills sets that could maintain the code until the program and its data undergo significant updating. Several key data sources (U.S. Census, California Household Travel Survey, Global Burden of Disease) are scheduled for updating within a few years of 2020.

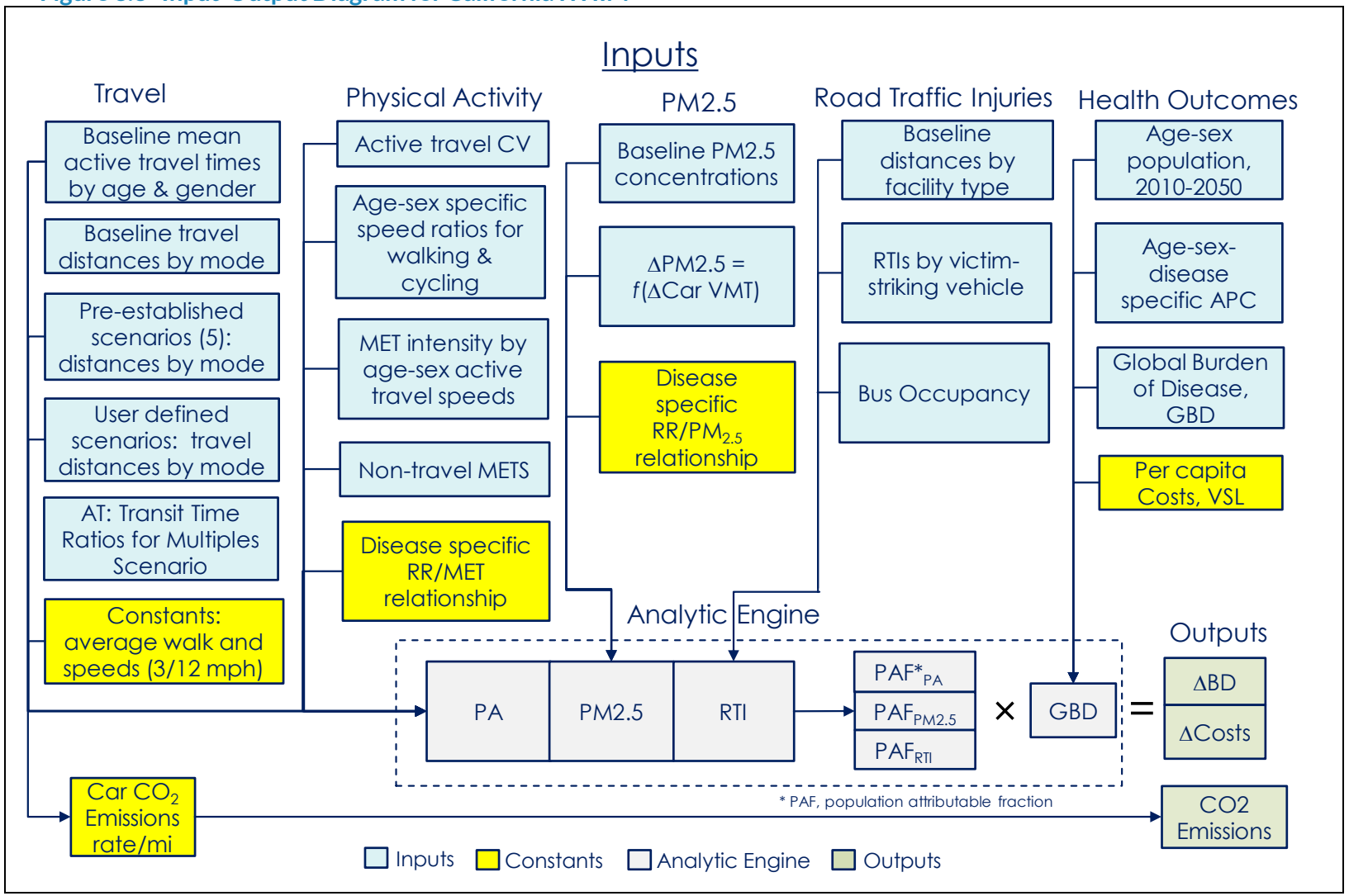
A schematic outline of the R/Shiny program is presented in Table 3.8. R Shiny applications are divided into two sections: 1) user interface (ui) and 2) server. The "ui" section contains the design elements of California ITHIM website and the "server" contains the commands for the analytic engine through the tool module.

ITHIM Tool

A key element of design is modularization. The website can be functionally divided into two components: 1) the core analytic and interactive tool appearing below ITHIM TOOL on the RunITHIM page, and 2) all the other webpages, which have static text and images. Detailed documentation of the Tool module and its R code are available at https://ww2.arb.ca.gov/ITHIM/CA_ITHIM_Tool_Documentation.pdf.

The Tool module is accessed in the Shiny interface in the RunITHIM tab panel [ithim_toolUI("TOOL")] and in the server [callModule(ithim_tool, "TOOL")]. This approach keeps the R code used to maintain the website's static narrative text and images apart from the dynamic and reactive R code that generates outputs (summary report, infographic, tables, and graphs). This also minimizes the risk of the application being rendered inoperable by unintentional changes in the tool portion when CARB staff performs website maintenance for the Home, About, Decision Support and User Support pages.

Figure 3.3 Input-Output Diagram for California ITHIM



APC, annual percent change; BD, burden of disease; CV, coefficient of variation of active travel time; GBD, global burden of disease; METS, Metabolic equivalent task; PA, physical activity; PM2.5, fine particulate matter with aerodynamic diameter of 2.5 microns; RR, relative risk; RTI, road traffic injuries; VMT, vehicle miles traveled; VSL value of a statistical life; mph, miles per hour constants

Figure 3.4 Schematic of Functions of the Analytic Engine of California ITHIM

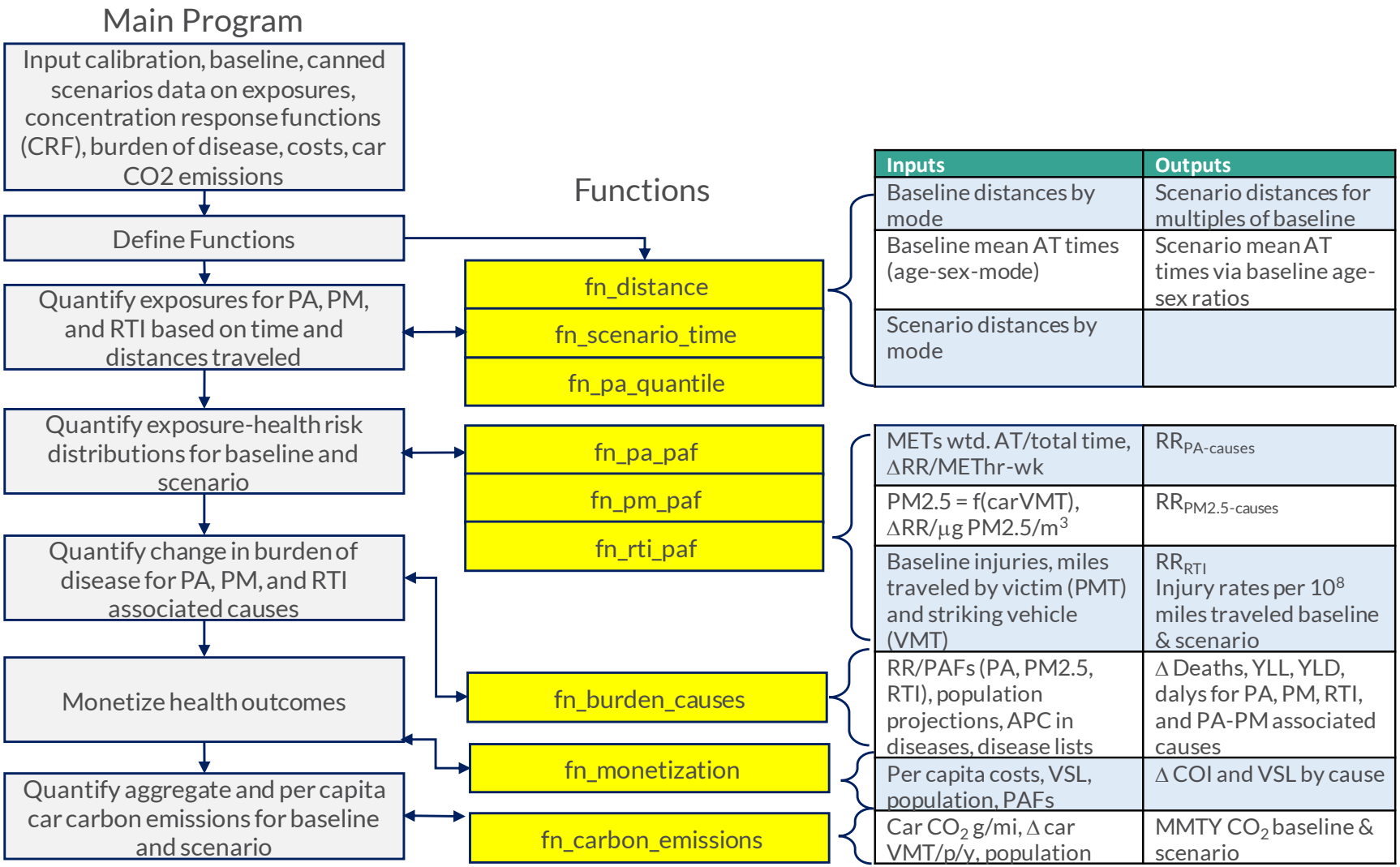


Table 3.7 Mathematical Basis for Functions in California ITHIM (app.R)

Functions "fn_scenario_time " and "fn_pa_quantile"	
Strata: *i*, age 1 to 8; *j*, gender (M, F); *k*, mode (walk, bike); *l* quintile (1 to 5); b = baseline, s = scenario	
$\boldsymbol{x}$, per capita mean weekly active travel minutes reported from California Household Travel Survey, CHTS, 2012	
$\boldsymbol{r}$, age-sex ratio of mean travel times ($\boldsymbol{x}$) by mode, $\boldsymbol{r_{ijk} = \frac{x_{ijk}}{x_{F15-29,k}}}$	
$\boldsymbol{t}$, population mean active travel time by mode derived from mean distance, d, and velocity, v, $\boldsymbol{t_k = \frac{d_{ijk}}{v_k}}$ where v_{walk}, 3; $v_{bike,}$ 12mph Distance, *d*, is based on origin-destination coordinates in CHTS, 2012; velocities, *v*, are MPO conventions	
CV, coefficient of variation in total active travel time (bike + walk)	
sd, standard deviation of active travel mean, $\boldsymbol{sd_{ijk} = CV * t_{ijk}}$	
P, proportion of population in the *ith-* , *jth* age-gender group	
vc, Age-sex walk velocity adjustment constants, $\boldsymbol{vc_{ijk} = \frac{v_{ijk}}{v_{..k}}}$	
p, percentile of the active travel physical activity time distribution (0.1, 0.3, 0.5 [median], 0.7, 0.9)	
Preprocessed inputs	
Baseline	Scenario
$\boldsymbol{t(b)_{ijk} = f(r_{ijk}, P_{ij}, t_{..k})}$ *CV* $\boldsymbol{MET_{ij,walk} = f[\frac{METS}{v}(Ainsworth), vc_{ij,walk}]}$ # $\boldsymbol{MET_{ij,bike} = 6}$	$\boldsymbol{t(s)_{..k} = \frac{d(s)_k}{v_k}}$
Program Functions	
Baseline	Scenario
e1: $\boldsymbol{t(b)_{ijkl} = f(exp[normalinv(\ln(t(b)_{ijk}), \ln(sd(b)_{ijk}, p_l), t_{ij.}])}$	$\boldsymbol{t(s)_{ijk} = f(r(b)_{ijk}, P_{ij}, t(s)_{..k})}$ † $\boldsymbol{CV(s) = CV(b) - 0.0015429 * [t(s)_{...} - t(b)_{...}]}$ $\boldsymbol{t(s)_{ijkl} =}$ $\boldsymbol{f(exp[normalinv(\ln(t(s)_{ijk}), \ln(sd(s)_{ijk}, p_l), t_{ij.}])}$
e2: $\boldsymbol{METhrwk(b)_{ijkl} = t(b)_{ijkl} * MET_{ij,k}}$	$\boldsymbol{METhrwk(s)_{ijkl} = t(s)_{ijkl} * MET_{ij,k}}$

Processed input that could be a program function; † $t(s)_{ijk}$ could be based on user input or a user specified $r(s)_{ijk}$

Table 3.7 Mathematical Basis for Functions in California ITHIM (app.R) continued

Functions "fn_pa_paf ", "fn_pm_paf", and "fn_burden causes"
Strata: *i*, age 1 to 8; *j*, gender (M, F); *k*, mode (walk, bike); *l* quintile (1 to 5); b = baseline, s = scenario; d = disease; n = exponent describing slope of dose-response curve; RR is the disease specific mortality risk per METhr-week
A. PAF for Physical Activity
If d(Ischemic heart disease, hypertensive heart disease, diabetes, stroke), then *METhrswk* = AT MET If d(dementia, depression, colon cancer, breast cancer, all causes), then *METhrswk* = travel MET + non-travel MET If total $METShrwk_{ijk}$ < 2.5 METS, then $METShrwk_{ijk}$ = 0.1 (minor physical activity) $$PAF_{ijd} = 1 - \frac{\Sigma\, RR_{ijld}^{(METhrswk,scenario)^n}}{\Sigma\, RR_{ijld}^{(METhrswk,baseline)^n}} = 1 - RR_{ijd}^{PA}$$ If RR < 1 then PAF = -PAF (change sign so to indicate decrease in burden of disease) RR = 1 for ages 0-4 and 5-14
B. PAF for PM2.5
Where β = 0.01293 for ischemic heart disease, hypertensive heart disease, stroke, and respiratory β = 0.013103 for lung cancer β = 0.009758 for acute respiratory infections in children < 5 years PM2.5 is ambient concentration as a function of car VMT [PM2.5 = f(car VMT, Region)] $$PAF_{ijd} = 1 - RR^{\beta_d(PM2.5_{Scenario} - PM2.5_{Baseline})}$$
C. PAF for combined pathways of ischemic heart disease, hypertensive heart disease, and stroke (other PA-related $RR^{PM2.5}$ = 1)
$$PAF_{ijd} = 1 - (RR_{ijd}^{PA} \times RR_{ijd}^{PM2.5})$$
D. Burden of disease, BD
Strata: *i*, age 1 to 8; *j*, gender (M, F); d = disease, yr = accounting year, $$BD_{i,j,d,yr} = localpop_{ij,yr} \times r_{i,j,d,baseline} \times (1 - APC_{i,j,d})^{(yr - yr_{baseline})}$$ Where, *localpop* = user-selected regional or county (within region) *r* = regional rate (x 10^5 Regional reference population) and regional deaths, yll, yld, and daly *APC* = annual percent change in age-, sex-, cause-specific mortality rate
E. Change in the Burden of disease, BD
$$\Delta BD_{i,j,d,yr} = PAF_{ij,d} \times BD_{ijd,yr}$$

Functions "fn_pa_paf ", "fn_pm_paf", and "fn_burden causes"

Strata: *i*, age 1 to 8; *j*, gender (M, F); b = baseline, s = scenario; st = striking vehicle mode, v=victim mode, VMT = vehicle miles traveled (striking vehicle), PMT = personal miles traveled (victim), sev = severity (fatal, serious), f = facility type (local, arterial, highway), n = safety in numbers exponent (default set at 0.5)

A. RR/PAF

$$RR_{sev} = \frac{\sum_{fac}\sum_{st,v} Injuries_s}{\sum_{fac}\sum_{st,v} Injuries_b}$$

Where $Injuries_s = ((VMT_{s,st} \times PMT_{s,v})^n \times Injuries_{b)/}(VMT_{b,st} \times PMT_{b,v})^n$

B. Burden of disease, BD for RTIs

Strata: *i*, age 1 to 8; *j*, gender (M, F); yr = accounting year,

$$BD_{i,j,d,yr} = localpop_{ij,yr} \times r_{i,j,baseline} \times (1 - APC_{i,j})^{(yr - yr_{baseline})}$$

Where, *localpop* = user-selected regional or county (within region)

r = regional rate (x 10^5 Regional reference population) and regional deaths, yll, yld, and daly

APC = annual percent change in age-, sex-, cause-specific mortality rate

C. Change in the Burden of disease, BD

$$\Delta Deaths = -(1 - RR_{fatal}) \times BD_{deaths}$$
$$\Delta YLL = -(1 - RR_{fatal}) \times BD_{yll}$$
$$\Delta YLD = -(1 - RR_{serious}) \times BD_{yld}$$
$$\Delta DALY = \Delta YLL + \Delta YLD$$

Table 3.8 Outline of the R Shiny Application (app.R), California ITHIM (Key Shiny Commands)

I. General Set-Up
- A. Read R libraries for Shiny, ggplot2, and other packages (library)
- B. Read input (csv) text and image management, and geographies for About >Geographies tables (read)

II. Shiny User Interface (ui)
- A. Title Panel (titlePanel)
- B. Main horizontal navigation bar and footer (navbarPage)
- C. Home page (tabPanel)
  1. Content and action buttons (actionButton)
- D. About page menu (navbarMenu)
  1. Introduction (tabPanel)
     a. Content (drawn from webtext.csv and webphotoimage.csv)
  2. Instructions (tabPanel)
     a. Content
  3. Scenarios (tabPanel)
     a. Content
  4. Geographies (tabPanel)
     a. Content
  5. Time Periods (tabPanel)
     a. Content
  6. Methods (tabPanel)
     a. Content

- E. RunITHIM Page
  1. ithim_toolUI("TOOL")

- F. Decision Support page menu (navbarMenu)
  1. Health Outcomes (tabPanel)
     a. Content
  2. Strategies - Introduction (tabPanel)
     a. Content
  3. Strategies - Physical Activity (tabPanel)
     a. Content
  4. Strategies - Safety (tabPanel)
     a. Content
  5. Strategies - Air Pollution, greenhouse gas emissions, car VMT (tabPanel)
     a. Content
  6. Evidence (tabPanel)
     a. Content

Table 3.8 Schematic Outline of the R Shiny application (app.R) for California ITHIM with Key R Shiny Commands (continued)

7. Data & Resources (tabPanel)
   a. Content
8. Evidence (tabPanel)
   a. Content

G. User Support page (tabPanel)

III. Shiny Server

A. callModule(ithim_tool, "TOOL")

B. Generate tables for About > Geographies (renderTable)

C. Execute Home page action buttons (updateNavbarPage)

D. Navigate between pages on website (updateTabsetPanel)

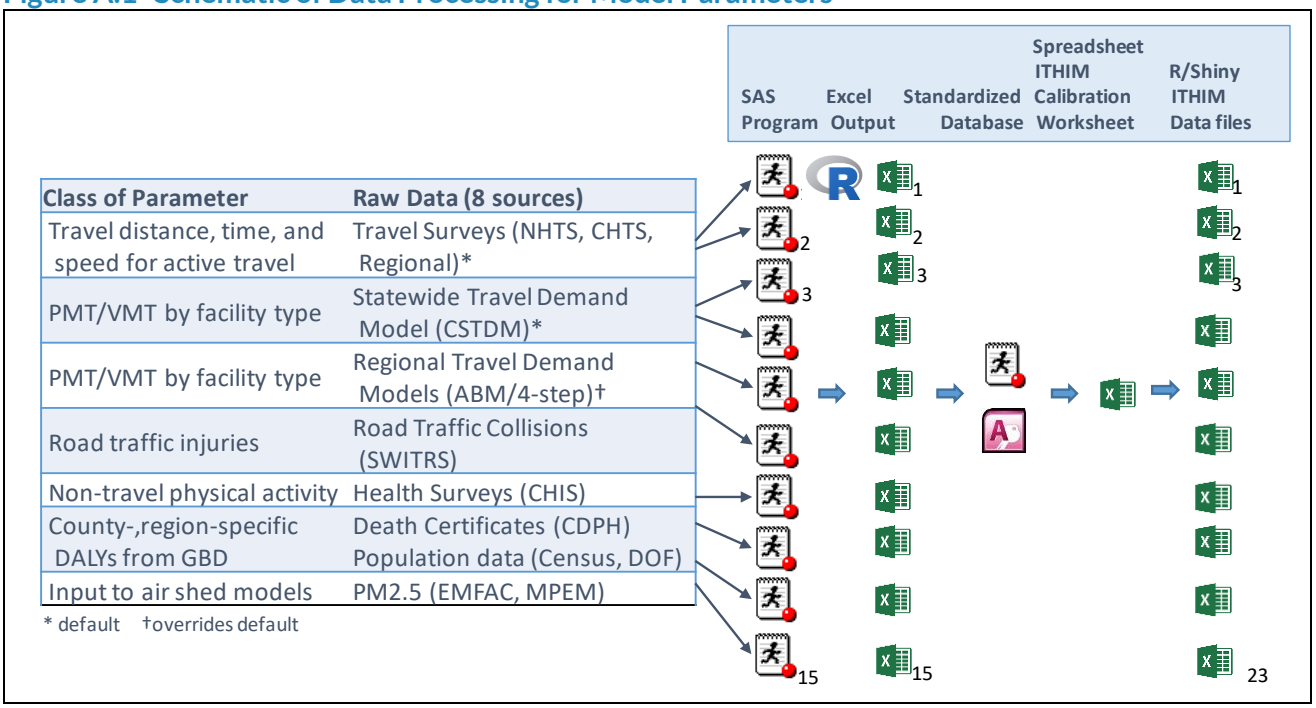
Chapter References

6. Physical Activity Guidelines Advisory Committee. *2018 Physical Activity Guidelines Advisory Committee Scientific Report*. Washington, DC: U.S. Department of Health and Human Services; 2018.https://health.gov/paguidelines/second-edition/report/.
21. RStudio. *Shiny R Package*. Boston, MA: RStudio; 2019.http://shiny.rstudio.com/. Accessed April 4, 2019.
22. Park T. *Bootswatch: Free themes for Bootstrap, Flatly*; 2016.https://bootswatch.com/flatly/. Accessed April 8, 2019.
23. Park T. *Introducing Bootswatch*; 2012.https://thomaspark.co/2012/02/introducing-bootswatch/. Accessed April 8, 2019.
24. Elvik R, Bjørnskau T. Safety-in-numbers: A systematic review and meta-analysis of evidence. *Safety Science*. 2015;doi:10.1016/j.ssci.2015.07.017.
25. US EnvironmentalProtection Agency. *Regulatory Impact Analysis for the Final Revisions to the National Ambient Air Quality Standards for Particulate Matter. Appendix 3.A, EPA-452/R-12-005*. Washington, DC: U.S. Environmental Protection Agency; 2013.https://www3.epa.gov/ttn/ecas/regdata/RIAs/finalria.pdf. Accessed April 12, 2019.
26. Lutsey N. Cost-effectiveness assessment of low-carbon vehicle and fuel technologies. *Trans Res Rec*. 2010;2191:90-99.
27. Maizlish N, Tomari K, Jiang C. *California ITHIM R/Shiny version (app.R)*. Davis: University of California; 2019.https://github.com/orgs/ucdavis/teams/ithim_california. Accessed April 10, 2019.

Appendix A. Creating California ITHIM Data Files from Primary Sources

Calibration data for the 2010 baseline and several scenarios was created by an automated process (Figure A.1) using batch programs in SAS or R that read disaggregated data from the source, usually as a downloadable file from the Internet.

Figure A.1 Schematic of Data Processing for Model Parameters



The programs carried out statistical analyses and created output in a standardized format, which was edited to the file specifications in Tables 3.4 and 3.5. The correspondence between the R and SAS programs and the California ITHIM calibration data files is presented in Table A. 1. Copies of the R and SAS programs are freely available and located at the Github repository of this project (https://github.com/orgs/ucdavis/teams/ithim_california).

The outputs for spreadsheet ITHIM were computed by region (Table 2.2). For R/Shiny ITHIM, the spreadsheet outputs for each region were manually consolidated in a single csv file for each major parameter (Table A.1). California totals were computed as 2010 population weighted averages of the regional values.

Table A.1 Correspondence between California ITHIM Calibration Files and SAS/R Batch Programs That Processed Primary Data

File Name	Data Processing Batch File/Method	Key Metric(s)
CalBurdenDisease2010.csv	item6_Age_sex_mortality_rates08-15-13.sas	Age-sex-disease specific adjustment factors for deaths, yll, yld, dalys
APC_Disease_Rates.csv	Manual extraction of data from Canudas et al,[15] compiled in spreadsheet ITHIM 'Disease Rates'	Annual average percent change in age-sex-disease specific mortality rates
DiseaseRiskAdjuster.csv	User-supplied data	Ratio of age-sex-disease specific mortality rate to age-sex-disease risk adjuster mortality rate
CO2g_mi.csv	EMFAC2014_CO2Emissions2016-04-135.R	CO2/mi
COI2010USD.csv	Manual extraction of data from Maizlish and Siegel[28] ; compiled from spreadsheet ITHIM 'Costs'	Disease-specific costs per capita, 2010
ATmean_min_week_age_sex_baseline.csv	CHTS2012ITHIM2016-03-26.R	Age-sex and mode (walk, bike) specific ratios of active travel time/p/w
bike_walk_cv.csv	Item4_CHIS2009_PA_Quintiles_SD8-30-13Confidential.sas	Coefficient of variation of the mean active travel time in the baseline year
METminWalk_Bike.csv	Manual extraction from spreadsheet ITHIM ('Baseline'!AD6:AG13) based on Ainsworth[29]	Age-sex-walk/bike METS
nonTravelMETS.csv	Item4_CHIS2009_PA_Quintiles_SD8-30-13Confidential.sas	Age-sex-quintile specific METS
Distances_mi_year_baseline.csv	CHTS2012ITHIM2016-03-26.R program for walk and bike; other modes vary by MPO	Mode-specific mi/p/y
Distances_mi_yr_scs.csv	Data extracted from MPO TDMs and MPO EIRs, expressed relative change from baseline (see Maizlish et al[1] for details)	Mode-specific mi/p/y
Distances_mi_yr_strip.csv	CHTS2012ITHIM2016-03-26.R	Mode-specific mi/p/y

File Name	Data Processing Batch File/Method	Key Metric(s)
Distances_mi_yr_ussg.csv	Spreadsheet ITHIM 'What If' Calculator for walk and bike were set to 75 median min/p/wk and distances calculated using walk at 3 mph and cycling at 12 mph	Walk and bike mi/p/w
Baseline_distance_by_facility_type.csv	Manual extraction of outputs of MPO and California Statewide Travel Demand model[30]	Percent of car, bus, truck travel by roadway (facility type)
PM25CARB2012.csv	Excel spreadsheet (ARBpopulation2010-2050PM25_IPT2019-03-08.xlsx) of EMFAC outputs and mortality incidence per ton data	Change in annual average ambient PM2.5 per percent change in car VMT
WalkBikeTransitRatios.csv	CHTS2012Bike_Walk_Transit_Ratio2016-03-28.R	Ratio walk/bike minutes to transit minutes
Bus_occupancy.csv	MPOs estimates	PMT/VMT for buses
ParameterDefaults.csv	Constants for travel, health outcomes, costs (Table 3.6)	Constants for travel, health outcomes, costs
age_sex_region2010.csv	Item5_CA2010_County_age-sex08-16-13.sas	USCensus_2010_SF1_QTP1
age_sex_region_county2010-2050.csv	Pop_Projections_20180731.R	CaDoF_2015-2050
PA_RR.csv	Manual extraction of spreadsheet ITHIM 'Phy activity RRs'!A4:AB4 (Woodcock et al[31])	Disease specific RR/MET-hr week
PM25_RR.csv	CARB recommendation based on Krewski et al 2009 for cardio-respiratory disease ARB; lung cancer and acute respiratory infections in children (Bart Ostro, personal communication, 2010)	Coefficient of concentration-response function for cardiopulmonary disease, lung cancer and acute respiratory infections in children
rti_baseline.csv	Victim_Striking_Vehicle_Injury2006-2010matrix9-10-13.sas; item13_rti_matrix9-23-15.sas	SWITRS, 2006-2010

Data Quality

In processing disaggregated data of health and travel surveys, raw data files were examined for missing data and unreasonable values. Using recommendations of the National Highway Cooperative Research Program[32] missing data on age and sex of survey respondents in the California Household Travel Survey 2012[18] were imputed using hot the deck method and unreasonable or missing values for trip times and distances were imputed using inference with non-missing data of related variables. Trip distances were reported in CHTS2012 using two methods: 1) distance on a roadway network from a Google Maps query of origin and destination coordinates, and 2) straight line distance between the coordinates ("crow fly"). Unreasonably long distances of "network" trips were identified comparing each trip's speed (distance/time) with reasonable maximum values (walk: 10 mi/h, bicycle: 24 mi/h; car, bus, truck, motor cycle: 75 mi/h). Straight line distances for individual trips not exceeding unreasonable maximum speeds replaced those trips with implausibly long network distances. Any remaining unreasonably long trip distances were recalculated using the maximum reasonable speed and reported time. Imputed values for trips with either a missing distance or time were based on speed, distance and time relationships. When trip distance was available but trip time was not, missing distances were imputed by dividing the travel distance by the average speed by mode derived from non-missing travel times and distances. When trip time was available but trip distance was not, missing times were imputed by multiplying the travel times by the average speed by mode derived from non-missing travel times and distances. Trips with 0 distances but non-zero travel times were considered loop trips. The distance for these trips – primarily by walking and bicycling – was imputed using the reported travel time multiplied by the average speed of trips with non-missing data for that mode.

The statistical stability of parameters derived from probability samples in survey data (e.g. mean walk or bicycle distances and times stratified by age and sex) was assessed by examining their relative standard error, RSE (sometimes called coefficient of variation). Parameters with an RSE greater than 0.3 were considered potentially unstable. Male and female bicyclists aged 70 and older were most likely to have sparse and statistically unstable data. Data from a larger geographic area or adjacent age cells were used to impute these unstable values as well as cells with no observations.

The following section provides detailed description for each of baseline calibration parameter.

Per Capita Mean Daily Travel Distance

This parameter is the "Baseline" variable in the "Distances_mi_year_baseline.csv" data file and was generated by CHTS2012ITHIM2016-03-26.R for active modes of travel from the 2012 California Household Travel Survey.[18] The survey, conducted at roughly 10 year intervals, is a county stratified sample of California's civilian population. Information is organized in 4 data files: household, person, vehicle, and trips, which are abstracted from a one day travel diary. The distance of each trip, *d*, for the *i*th mode taken was aggregated for each person, *j*, taking into account the probability of selection, *w*, as:

$$\text{Mean Distance}_i = \frac{\sum_{i,j} d_{i,j} \times w_{i,j}}{\sum_{i,j} w_{i,j}} \text{ where i = pedestrian, bicyclist, car, truck, motorcycle, bus, rail}$$

For modes with assumed occupancy of 1 (walk, bicycle, and truck), this is a measure of both

personal miles traveled (PMT) and vehicle miles traveled (VMT). For car (driver + passengers), bus and rail, this is a measure of PMT. This measure for car-driver is equivalent to car VMT.

The population mean travel distance includes all members of the population in the denominator, including those that did not travel at all or by a specific mode. The calculation of the standard error of this parameter took into account clustering of individuals within households

Age, Sex, and Mode-Specific Per Capita Mean Daily Active Travel Time (Baseline)

Walking, bicycling, and health outcomes are strongly influenced by the age and gender distribution of a population. This parameter is the "Baseline" variable in the "ATmean_min_week_age_sex_baseline.csv" data file, and was generated by CHTS2012ITHIM2016-03-26.R for active modes of travel from the 2012 California Household Travel Survey.[18] The numerator is the sum of daily active travel time (min.) for each person in an age-sex stratum for each mode. The denominator is the count of persons of each age-sex stratum in the population, which includes the entire population, even those who did not travel.

$$Mean_{i,j,k} = \frac{\sum min_{i,j,k} \times wt_{i,j,k}}{\sum Population_{i,j,k} \times w_{i,j,k}},$$

where *i* = age group, *j* = gender and *k*= mode (walk, bicycle), and wt is the sample weight

To project per capita mean age-sex- and walk (and bicycle) travel time for future populations and scenarios, the ratio, R, of age-sex- and walk (and bicycle) specific per capita mean baseline travel time relative to females aged 25 years was used to derive age-sex and mode-specific per capita means for the scenario from the scenario's overall mode-specific per capita mean travel time and the age-sex distribution of the scenario population.

$$R_{i,j,k,0} = \frac{min_{i,j,k,0}}{min_{f25,k,0}}$$

where $min_{f25,k,0}$ is the per capita mean minutes of the k^{th} mode (walk, bicycle) for women aged 15-29 years at baseline, 0 .

The sum of the ratios is given by:

$$R_{..k,0} = \sum R_{i,j,k,0}$$

The scenario age-sex and mode per capita mean minutes of active travel is derived from the overall scenario per capita mean active travel time and the age-sex population percentages of the scenario population. The mode-specific overall per capita mean for the scenario is represented by:

$$Scenario\ per\ capita\ mean\ travel\ time = min..k1$$

where k is the mode (walk, bicycle) and 1 represents the scenario. The age-sex stratum specific per capita mean active travel time for scenario and kth mode is:

$$min_{i,j,k1} = R_{i,j,k,0} \times \left(\frac{n_{i,j}}{n..} \Big/ R_{..k0} \right) \times \left(min_{..k1} \Big/ \frac{n_{i,j}}{n_{..}} \right)$$

Where $n_{i,j}$ is the age-sex stratum population count and n.. is the population total.

In California ITHIM the overall scenario mean walking and bicycling times were derived from their scenario distances and assumed average speed of 3 mi/h and 12 mi/h, respectively. This approach was taken due to limitations in predicting or modeling age-sex specific active travel time in future populations. Some MPO travel models do not allocate bicycle trips by gender, and there are no readily available data that reliably predict demonstrate the relationship between mean age-sex travel times and changes in bicycle mode share. In countries with high active travel mode shares, women are as likely as men to ride bicycles and a cycling is common across age groups. This contrasts with the California experience for cycling, which tends to be more common in young adult males than other age-sex groups.

This approach for deriving age-sex active travel times for scenarios makes a key assumption that the age-sex ratios, R, at baseline do not change over time or in response to increases in mode share for active travel in scenarios.

Standard Deviation of Per Capita Mean Daily Active Travel Time

Travel times for active transport in most urbanized populations have a log normal distribution (Chapter 1. Figure 1.3). California ITHIM approximates this distribution in quintiles. The shape of the log normal distribution can be estimated from an inverse transform of the arithmetic mean and its standard deviation. (Note: this item is not the standard error of a survey mean, but the standard deviation of active travel time data in the population).

Both the mean and standard deviation can be estimated from travel and health surveys. While it is possible to estimate the standard deviation from travel surveys, which typically only sample a one-day diary, California ITHIM takes advantage of the 2009 CHIS Adult survey,[33] which includes questions on walking for transport over 7 days. This longer time period of measuring travel time is consistent with epidemiologic studies that associate health outcomes per week of physical activity. Standard deviations based on a 7 day anchor period tend to be larger than those based on 1 day anchor periods. Because CHIS does not explicitly query bicycling for transport, this item uses NHTS2009 data (age-sex specific bike:walk time ratios) to estimate the bicycle contribution to the overall active transport.

The calculation for the 2010 baseline of active travel was implemented in the batch program 'Item4_CHIS2009_PA_Quintiles_SD8-30-13Confidential.sas', which takes into account the complex survey design of CHIS and sample weights. In addition to the standard deviation, the coefficient of variation (standard deviation divided by the mean) was also calculated for baseline active travel.

To predict the standard deviation for scenario active travel time, California ITHIM takes into account the empirical observation that as active travel mode share increases, the variability in travel times decreases. California ITHIM uses data from European populations (Woodcock, 2011

unpublished) to model the relationship between increasing per capita active travel time and decreasing population variability, CV.

$$CV_1 = -0.0015429 \times (AT_1 - AT_0) + CV_0$$

where 0 indicates baseline and 1 indicates scenario, and *AT* is the per capita mean active travel time (walking + bicycling).

Distribution of Population by Age and Gender

The age and sex distribution of the state, regional, and county populations is expressed as a proportion of the total population based on data from the 2010 US Census 100% enumeration[34] and projections from the California Department of Finance for 2015 to 2050. [11]

$$\text{Proportion}_{i,j} = \frac{n_{i,j}}{N_{i,j}},$$

where *n* is the number of individuals in the *i*th age and *j*th sex category and *N* is the total number of individuals in the population. This data for item ('age_sex_region2010.csv) was generated for 2010 using the file 'Item5_CA2010_County_age-sex08-16-13.sas'. The R batch file ('Pop_Projections_20180731.R ') was used generate annual average projections ('age_sex_region_county2010-2050.csv') from 2015 to 2050 in 5-calendar year intervals (2015-2019, 2020-2024, 2025-2029, 2030-2034, 2035-2039,2040-2044, 2045-2049, 2050-2054).

Age-Sex-Disease-County Specific Mortality Rate Ratio

The burden of disease due to specific causes has been estimated at the country level by the World Health Organization.[35] To reflect disease rates experienced at specific California geographies, the mortality rates published in the 2010 U.S. Global Burden of Disease database were multiplied by the ratio of the age-sex specific mortality rate of the California geography and the age-sex specific rate in the U.S. population, or disease-age-sex specific rate ratio, RR.

$$\text{Rate Ratio}_{i,j} = \frac{CADR_{i,j,k}}{USDR_{i,j,k}},$$

where CADR is a California county-specific death rate for the *i*th age group, *j*th sex, and *k*th diagnostic category and USDR is the corresponding U.S. death rate. The file 'item6_Age_sex_mortality_rates08-15-13.sas' was used to calculate the age-, sex-, county-, and cause specific mortality rates using data from the California Department of Public Health (Statistical Death Master File) for deaths from 2009 to 2011.[36]

The age-sex and disease-specific mortality rates for the U.S. population are included in the 2010 GBD database.[13] Diagnostic categories were based on the International Classification of Diseases, 10th Revision (Table .3).

Table A.3 Global Burden of Disease Cause Categories and Corresponding ICD-10 Codes

Title in Global Burden of Disease Database	ICD-10*
Colon and rectum cancers	C18-C21, D01.0-D01.3, D37.3-D37.5
Breast Cancer	C50, D0.5-D05.9, D48.6
Cardiovascular Disease	
Hypertensive heart disease	I11
Ischemic heart disease	I20-I25
Cerebrovascular disease	I60-I63 I65-I67, I69.0, I69.1, I69.2, I69.3
Alzheimer and other dementias	F00-F03, G30-G31
Diabetes mellitus	E10-E13 (except E10.2, E11.2, E12.2, E13.2)
Depression (major depressive disorders)	F32-F33
Road Injuries	V01-V04, V06, V09, V10-V19, V20-V29, Y85.0, V30-V79, V87.2-V87.3, V80, V82
Cardio-respiratory: a. Lower respiratory infections, upper respiratory infections b. Same as cardiovascular above + inflammatory heart diseases c. Chronic obstructive pulmonary disease, Asthma, Other respiratory diseases	 J09-J11, J13, J14, J12.1, J12 (except J12.1), J15-J22, J85, P23, J00-J06 I11, I20-I25, I60-I63 I65-I67, I69.0, I69.1, I69.2, I69.3, I40, I42 J40-J44, J45-45, J47, J30-J39, J66-J70(except J69), J82, J92, J93.0, J93.1, J95, J98 (except J98.1, J98.2, J98.3, J98.9)
Lung cancer (Trachea, bronchus and lung)	C33-C34 , D02.1-D02.2, D38.1
Acute Respiratory Infections (children < 5 years) Lower respiratory infections, upper respiratory infections	 J09-J11, J13, J14, J12.1, J12 (except J12.1), J15-J22, J85, P23, J00-J06

To avoid unstable estimates of the RR, age-sex cells with fewer than 10 deaths were not adjusted (RR=1). This usually occurred in the youngest age groups, which contribute few DALYs to the overall burden of disease.

Proportion of Colon Cancers from All Colo-Rectal Cancers

Epidemiologic studies associate physical activity with reductions in colon cancers, rather than the broader diagnostic category of colo-rectal cancers. This parameter input is used to limit the burden of disease to colon cancers. The source of data is the CDPH Death Statistical Master file for the years 2009 to 2011. The sex-specific proportion of colon cancers from colo-rectal cancers is given by:

$$\text{Proportion of colon cancer deaths to all colorectal cancers}_{i,j} = \frac{\text{Colon cancer deaths}_{i,j}}{\text{Colorectal cancer deaths}_{i,j}}$$

where I = region and j = sex category.

The ' item7_colon_colorectal08-16-13.sas' batch file carried out the calculations, whose results were incorporated into the 'CalBurdenDisease2010.csv' data file.

Per Capita Weekly Non-travel Related Physical Activity

California ITHIM parses total physical activity into categories for active travel and non-travel related physical activity. Ideally, the same data source would have both travel related and non-travel-related physical activity. Unfortunately, travel surveys do not typically have detail on non-travel related physical activity. The CHIS2009 Adult survey has some overlapping information on average weekly minutes of walking for transport and average weekly minutes of non-travel related physical activity of a moderate and vigorous intensity and working status. By using the age-sex specific ratios of walking time to bicycling time reported in the CHTS2012, weekly total active travel (walk and bicycle) can be estimated from CHIS data.

This distribution of activity time was weighted by the intensity of physical activity, METS (kcal/kg/hr), using standard values from Ainsworth[29] and divided into quintiles of active travel. The median non-travel physical activity was calculated for each quintile of travel related physical activity. Because specific occupations were not reported in the CHIS2009, a weighted average of METS based on the CHIS2005 occupational distribution (1.6 METS) was multiplied by weekly work hours in the CHIS2009.

The batch file 'Item4_CHIS2009_PA_Quintiles_SD8-30-13Confidential.sas' carried out the calculations that were incorporated into 'nonTravel METS.csv.'

Proportion of Vehicle Miles Traveled (VMT) by Facility Type

The calculation of road traffic injuries takes into account the facility type on which the injury occurred. Roadway types are designed to accommodate vehicle travel at a range of speeds and traffic volume, and stratification of injury rates by facility type takes into account speed and volume. ITHIM categorizes facility types as highways, arterials, and local roads. The proportion of travel by facility type is calculated for each mode (walk, bike, car, bus, truck, and motorcycle). Due to limited data, the distribution of walking is assumed to be 75% on local roads and 25% on arterials, and a negligible percent on highways. Based on studies by Dill,[37] we estimate 53% of bicycle travel on local roads, 47% on arterials, and a negligible percent on highways. Travel model data are used to provide breakdowns by facility type for other modes.

A crosswalk between federal classifications of facility types and the three California ITHIM categories is presented in Table A.4. These classifications are roadway attributes in U.S. Census TIGER files that were used to classify the facility type for collisions in the SWITRS database (see below). MPOs use different facility type categories in their travel demand models, which require a MPO-specific crosswalk to California ITHIM.

Bus Occupancy

Some regional travel demand models do not account for bus travel on a roadway network, which makes it difficult to estimate overall bus VMT and the distribution of bus VMT by roadway type. Travel surveys report bus PMT, so it is possible to estimate total bus VMT, if occupancy is known (Bus VMT = Bus PMT/Bus Occupancy). An alternative data source for bus VMT and its

Table 2.4 Crosswalk Between Facility Type Classification (rttype and mtfcc) in TIGER Line Files and ITHIM

ITHIM Roadway	Rttyp Code	Mtfcc Code	Type of Facility
arterial	M	S1100	Common Name-Primary Road
arterial	S	S1100	State recognized-Primary Road
arterial		S1630	Ramp
arterial	C	S1200	County-Secondary Road
arterial	U	S1100	U.S.-Primary Road
arterial		S1640	Service Drive usually along a limited access highway
arterial	M	S1640	Common Name-Service Drive usually along a limited access highway
arterial	M	S1630	Common Name-Ramp
highway	I	S1100	Interstate-Primary Road
highway	I	S1200	Interstate-Secondary Road
local	M	S1200	Common Name-Secondary Road
local	S	S1200	State recognized-Secondary Road
local	M	S1400	Common Name-Local Neighborhood Road, Rural Road, City Street
local		S1730	Alley
local	C	S1400	County-Local Neighborhood Road, Rural Road, City Street
local	U	S1200	U.S.-Secondary Road
local		S1400	Local Neighborhood Road, Rural Road, City Street
local	M	S1740	Common Name-Private Road for service vehicles (logging, oil fields, ranches, etc.)
local	M	S1500	Common Name-Vehicular Trail (4WD)
local	O	S1400	Other-Local Neighborhood Road, Rural Road, City Street
local	M	S1710	Common Name-Walkway/Pedestrian Trail
local	S	S1400	State recognized-Local Neighborhood Road, Rural Road, City Street
local		S1500	Vehicular Trail (4WD)
local	U	S1400	U.S.-Local Neighborhood Road, Rural Road, City Street
local	O	S1200	Other-Secondary Road
local		S1740	Private Road for service vehicles (logging, oil fields, ranches, etc.)
local	O	S1100	Other-Primary Road
local	M	S1750	Common Name-Private Driveway
local	M	S1730	Common Name-Alley
local		S1780	Parking Lot Road
local	O	S1740	Other-Private Road for service vehicles (logging, oil fields, ranches, etc.)
local		S1750	Private Driveway
local		S1710	Walkway/Pedestrian Trail

distribution by roadway type is bus routes and their weekday and weekend schedules, and administrative reports of revenue miles published by local transit authorities. Occupancy generated by this merging of different data sources should be checked for reasonableness.

CO_2 Emitted per Distance Traveled

Most large MPOs use emissions models like EMFAC[38] to estimate historical and projected levels of CO_2 emitted per car mile travelled based on the characteristics of the regional vehicle fleet. The emission factor used for CO_2 emissions of the SF Bay Area was derived from EMFAC2014 using an R program that calculated VMT-weighted average by fuel type (gas, diesel, or electric). The operating conditions included vehicle start-up and running in a carbon accounting base year (2000), the travel baseline (2010), and a future year (2040). In California, carbon emissions after 2000 are often expressed relative to those generated in 2000.

This information was used to calculate the aggregate car carbon emissions generated by a future population based on the carbon emissions factor, EF (grams CO_2/m), projected mean per capita car VMT and the future population size ('worksheet 'CO2US').

$$Aggregate\ CO_2\ Emissions = EF \times mean\ per\ capita\ car\ VMT \times Population$$

The VMT-weighted emissions factor was generated by the R batch file 'EMFAC2017_2010_2050CO2.R ' and incorporated into the ' CO2g_mi.csv' data file, where it is expressed as grams of CO_2 emitted per car VMT/y.

Walk Transit Ratios

For the 'Baseline Multiples' scenario, users specify the relative change from the 2010 Baseline in distances walked, biked, and ridden in transit. For the transit component, the ratio, R, of walk time to transit time and the ratio of bicycle time to transit time were used to estimate transit-associated walking and cycling. This was calculated from the trip file in the California Household Travel Survey, which numbers trips in sequence and includes the mode for each trip. Each trip, n, before (n-1) and after (n+1) a bus or rail trip that was a walk trip (or bike trip) could be identified. The minutes associated with all walk trips (before and after) transit trips were summed as were minutes of those transit trips.

$$R_i = \frac{\sum min_{i,n}}{\sum min_{transit,n}}$$

where *i* is the *i*th mode (walk, bike).

Thus, by using these ratios, walking and cycling times associated with increases in transit time could be estimated. This ratio approach assumes that the relationship between increased active travel time increases linearly with increase transit times (i.e. people will walk and bike further to regional transit than local transit). The R batch file 'CHTS2012Bike_Walk_Transit_Ratio2016-03-28.R ' carried out the calculations and the output was incorporated into 'WalkBikeTransitRatios.csv '

Collisions Between Striking Vehicle and Victim Vehicle

Injuries between striking vehicle and victim vehicle were generated from the Statewide Integrated Traffic Records System (SWITRS)[16] and geocoded by the University of California, Berkeley Safety Transportation Resource and Education Center (SAFETREC) in its Traffic Injury Management System (TIMS).[17] The collision, party, and injury files were joined in SAS and a

dataset was created for the 76,899 severe and fatal California injuries occurring between 2006 and 2010. Collision coordinates of these injuries were spatially joined in ArcGIS 10.2 with TIGER LINE roadway files from the US Census.[39] Latitude and longitude coordinates were missing for 8.6% of injuries, which could not be geocoded. The spatial join was done by county, and we developed a Python routine for assigning facility type from classifications in the TIGER LINE files to each injury (Table 2.4).

SAS batch files (Victim_Striking_Vehicle_Injury2006-2010matrix9-10-13.sas; item13_rti_matrix9-23-15.sas) were applied to these data to sum fatal and serious injuries for 3 different roadway types for single party accidents and for ≥2 party collisions for every pair-wise combination of modes for a striking vehicle (*i*) and victim vehicle(*j*):

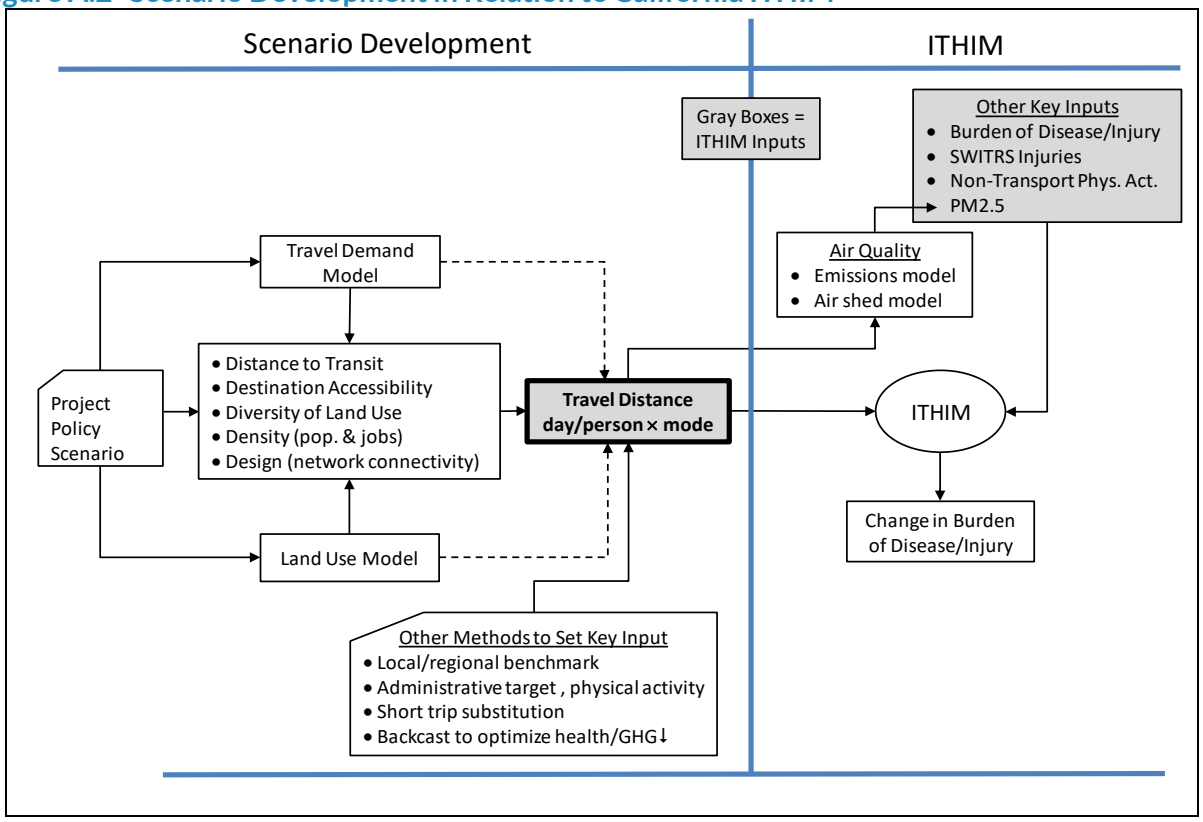
$$Injuries_{ij,k,l}$$

where *ij* is a collision pair (e.g. pedestrian-car), *k* is injury severity (serious, fatal), and is roadway type (local, arterial, highway). The results were incorporated into the file ' rti_baseline.csv'.

Scenario Data

Scenario development is outside the scope of California ITHIM. The inputs to ITHIM are often the outputs of other models which examine how projects, policies, infrastructure investments alter travel behavior. Other ways in which scenarios may be developed are forecasting current trends or backcasting a goal, such as achieving a particular population level of physical activity.

Figure A.2 Scenario Development in Relation to California ITHIM



Chapter References

1. Maizlish N, Linesch N, Woodcock J. Health and greenhouse gas mitigation benefits of ambitious expansion of cycling, walking, and transit in California. *J Transp Health.* 2017;http://dx.doi.org/10.1016/j.jth.2017.04.11.
11. Demographic Research Unit. *Report P-3. State and County Male (Female) Population Projections by Race/Ethnicity and Detailed Age, 2010 through 2060 (as of July 1).* Sacramento, CA: California Department of Finance; 2014.http://www.dof.ca.gov/Forecasting/Demographics/Projections/.
13. Institute for Health Metrics and Evaluation (IHME). *Global Burden of Disease (GBD).* Seattle, WA: Institute for Health Metrics, University of Washington; 2015.http://www.healthdata.org/gbd.
15. Canudas-Romo V, DuGoff E, Wu AW, Ahmed S, Anderson G. Life Expectancy in 2040: What Do Clinical Experts Expect? *North American Actuarial Journal.* 2016;20(3):276-285.
16. California Highway Patrol. *2008 Annual Report of Fatal and Injury Motor Vehicle Traffic Collisions. Statewide Integrated Traffic Records System (SWITRS).* Sacramento: California Highway Patrol; 2008.www.chp.ca.gov/switrs/index.htm, accessed 8/2/2010.
17. Safety Transportation Research and Education Center. *Traffic Injury Mapping System.* Berkeley, CA: University of California; 2011.http://tims.berkeley.edu/index.php.
18. NuStats. *2010-2012 California Household Travel Survey Final Report.* Austin, TX: NuStats 2013.http://www.dot.ca.gov/hq/tpp/offices/omsp/statewide_travel_analysis/files/CHTS_Final_Report_June_2013.pdf.
28. Maizlish N, Siegel Z. *Monetizing Health Co-benefits from Transportation Strategies that Reduce Greenhouse Gas Emissions in the San Francisco Bay Area. Presented at the Annual Meeting of the American Public Health, San Francisco, October 21, 2012.* Richmond, CA: California Department of Public Health; 2012.
29. Ainsworth BE, Haskell WL, Herrmann SD, Meckes N, Bassett Jr DR, Tudor-Locke C, et al. 2011 Compendium of Physical Activities: a second update of codes and MET values. *Med Sci Sports Exercise.* 2011;43(8):1575-1581.
30. Statewide Modeling Branch. *California Statewide Travel Demand Model.* Sacramento, CA: California Department of Transportation; 2009.http://www.dot.ca.gov/hq/tpp/offices/omsp/statewide_modeling/cstdm_trip_tables_2009_CSTDM.html.
31. 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. *Lancet.* 2009;374:1930-1943.11. Demographic Research Unit. *P-3: State and County Projections Dataset.* Sacramento, CA: California Department of Finance; 2019.http://www.dof.ca.gov/Forecasting/Demographics/Projections/P3_Complete.zip. Accessed August 9, 2019.
32. Stopher PR, Alsnih R, Wilmot CG, Stecher C, Pratt J, Zmud J, et al. *Standardized Procedures for Personal Travel Surveys. NCHRP Report 571.* Washington, DC: National Highway Cooperative Research Program, Transportation Research Board; 2008.http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_571.pdf.
33. UCLA Center for Health Policy Research. *California Health Interview Survey (CHIS). Adult Survey.* Los Angeles: University of California; 2009.
34. U.S. Bureau of the Census. *2010 Census P.L. 94-171 Summary File.* Washington, DC: U.S. Bureau of the Census; 2010.http://www2.census.gov/census_2010/redistricting_file--pl_94-171/. Accessed May 15, 2011.

35. US Burden of Disease Collaborators. The state of US health, 1990-2010: Burden of diseases, injuries, and risk factors. *JAMA.* 2013;doi:10.10001/jama.2013.13805 Published online July 10, 2013.
36. Vital Statistics Unit, Health Information and Research Section. *Death Statistical Master File*. Sacramento, CA: California Department of Public Health; 2007-2009.
37. Dill J. Bicycling for Transportation and Health: The Role of Infrastructure. *J Public Health Policy*. 2009;30:S95–S110.
38. California Air Resources Board. *EMission FACtors (EMFAC) model, 2007*. Sacramento, CA: California Air Resources Board; 2007.http://arb.ca.gov/msei/onroad/latest_version.htm. Accessed October 14, 2011.
39. U.S. Bureau of Census. *2012 TIGER/Line Shapefiles*. Washington DC: U.S. Bureau of Census; 2012.http://www2.census.gov/geo/tiger/TIGER2012/. Accessed August 28, 2013.

Appendix B. Integration of ITHIM with Travel Demand Models

Vehicle miles traveled by mode and facility type can be obtained from activity-based and 4-step travel demand models. These measures are available from the *trip list* and the *loaded network* of a travel model. These model outputs are described generically and then illustrated using the Metropolitan Planning Commission's (MTC) Travel Model One.

Trip List

This is a comprehensive list of all trips made in the universe of the model. A *trip* occurs any time there is movement from one location to another. A *tour* is a chain of trips which begin and end at the same location (i.e. home or work). The trip list is useful for the inputs of:

- Per capita mean daily travel distance
- Per capita mean daily travel time
- Personal travel distance by facility type,
- Vehicle distance traveled (VMT) by facility type

The trip list is generally stored as a text file (CSV) with key fields being origin/destination transportation analysis zone (TAZ), mode, person ID, purpose, time of day. Most TAZs conform to the boundaries of census tracts. The origin, destination, mode, time of day combination can be used to look up a distance and a time value associated with the trip and the person ID is used to look up age, sex, and other demographic information that might be part of an equity analysis. Once these variables are incorporated into the master trip list, the travel times and distances can be aggregated by age, sex, and mode. Before processing the trip list, it is necessary to use a "skim matrix" to provide the travel time and distance.

Skims

A *skim* is a matrix with a column and row for every TAZ in the system (Figure B.1). The cell given by the *ith* row and *jth* column depicts a travel time or distance. The matrix is stratified by time of day and mode. The MTC model has 18 modes. Because California ITHIM modes do not correspond exactly to the MTC modes, MTC modes must be cross-walked to ITHIM categories. For example the MTC model mode "walk-transit-walk" gives a travel time for a particular origin/destination pair; however, the time of the trip is the combined time of the walk access, the wait for transit, and the walk egress. Since "walk to transit" is included with all other walking in ITHIM, walk time and in-vehicle transit time in ABM data must be parsed into separate mode categories. This is accomplished by a computer batch file, which reads the MTC travel model modes and creates new skim files depicting the travel time in the ITHIM modes for every origin-destination combination. The code of the batch file is available upon request, but must be run with proprietary software (Cube, Citilabs, Inc.). The skims (pairwise TAZ distance and times) must be joined to the trip list.

Figure B.1 Example of a skim matrix of times between origin and destination centroids of traffic analysis zones by vehicle mode

HwyPK.skm-*1 SOVTime

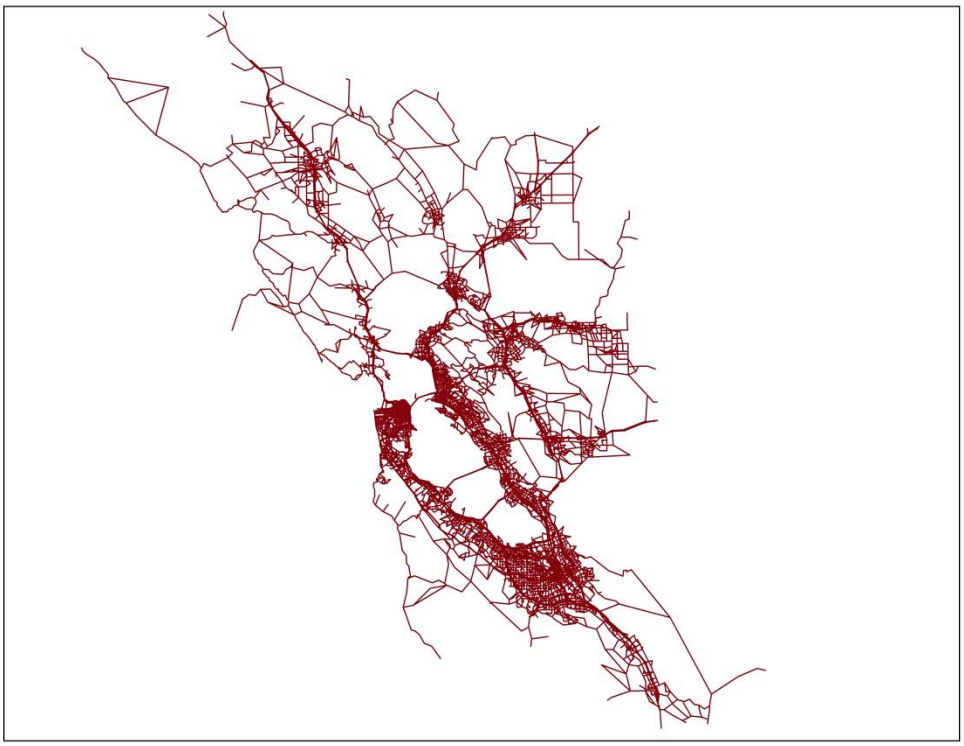
*1 SOVTime | 2 SOVDist | 3 SOVToll | 4 HOVTime | 5 HOVDist | 6 HOVToll | 7 TDTime | 8 TDDist | 9 TrkTime | 10 TrkDist

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	3.42	6.16	10.33	12.41	16.26	11.14	12.57	16.33	18.26	15.14	17.86	20.43	18.87	23.73	22.07
2	6.16	3.17	7.65	7.91	11.88	6.64	9.00	11.83	13.77	10.65	13.38	15.95	14.37	19.24	17.59
3	10.22	8.18	2.16	4.38	6.99	6.50	3.29	11.69	13.62	9.83	9.68	11.33	11.83	15.35	13.89
4	12.43	7.92	4.34	2.57	7.49	6.23	3.79	11.42	13.36	10.24	10.18	11.83	12.33	15.86	14.40
5	15.75	11.41	6.35	6.89	2.66	5.34	4.41	7.08	9.39	5.24	3.65	6.21	5.79	9.50	7.86
6	11.24	6.74	6.04	6.32	5.90	3.30	4.86	7.09	9.02	5.75	7.58	10.16	8.58	13.45	11.80
7	12.66	8.99	3.25	3.80	5.01	4.86	2.13	9.98	11.99	7.85	7.70	9.36	9.85	13.38	11.92
8	16.47	11.96	11.28	11.55	7.77	7.12	9.98	1.96	2.90	3.44	5.88	7.23	4.91	10.44	8.79
9	18.40	13.89	13.21	13.48	10.09	9.06	12.03	2.90	2.30	5.37	8.20	6.95	4.33	8.57	7.27
10	15.27	10.77	9.77	10.32	5.93	5.74	7.84	3.44	5.37	2.80	5.68	8.25	6.67	11.55	9.89
11	18.00	13.50	9.75	10.30	4.36	7.59	7.82	5.88	8.19	5.70	2.40	3.06	4.60	7.12	6.47
12	20.51	16.01	11.25	11.79	6.86	10.10	9.30	7.18	6.94	8.20	3.02	2.15	3.84	5.63	4.98
13	19.00	14.49	11.83	12.38	6.43	8.58	9.89	4.91	4.34	6.68	4.55	3.83	2.55	6.86	5.21
14	23.81	19.31	15.28	15.83	10.16	13.40	13.34	10.44	8.54	11.49	7.08	5.64	6.86	2.09	3.32
15	22.17	17.67	13.91	14.46	8.52	11.76	11.97	8.80	7.26	9.85	6.43	4.98	5.22	3.34	2.62
16	24.43	19.92	17.81	18.36	12.69	14.00	15.88	10.34	8.43	12.11	9.62	8.17	8.14	4.30	4.75
17	26.02	21.52	20.62	21.12	15.50	16.68	18.69	10.52	9.58	12.99	12.43	10.98	10.96	7.12	7.57
18	22.32	17.81	15.90	16.45	10.94	11.90	13.97	7.33	6.30	9.80	8.86	7.40	6.03	6.53	5.22
19	13.13	17.69	11.58	15.39	18.00	17.82	14.31	22.94	24.94	20.84	19.16	20.54	22.02	24.35	23.90
20	7.88	12.44	6.33	10.53	13.14	12.65	9.44	17.84	19.77	15.98	15.83	17.48	17.98	21.50	20.04
21	7.08	12.05	12.33	15.70	19.14	14.44	15.45	19.63	21.57	18.45	21.12	23.48	22.15	26.99	25.34

Loaded Networks

Loaded network files are a spatial representation of every travel link in the region, highways, arterials, and local roads (Figure B.2). Each trip in the trip lists is "loaded" onto the travel network creating a congested network, and trips are reassigned by a computer algorithm until there is an equilibrium (i.e. further iterations converge). The trip distribution at convergence is written out as GIS shape files which include a .dbf file whose rows for each link has attributes such as length, roadway type, automobile volume, and truck volume. With a lookup table from ABM facility type to ITHIM roadway type, an aggregation of VMT by ITHIM facility type becomes possible. VMT is generally not calculated in these attribute files but it can be obtained by multiplying the total amount of vehicle volume by the length (in miles) of each link. The loaded networks can provide slightly different VMT than the trip lists because of error at the end points and on centroid connectors. Based on advice of travel modelers at MTC, we use the trip list VMT measure for VMT and the loaded networks to calculate the *proportion* of VMT on each roadway type.

Figure B.2 MTC Travel Network



Data Processing

Data processing has been implemented at MTC using both SAS and R code. Please contact Dr. Maizlish or Lisa Zorn (lzorn@mtc.gov) if you would like to obtain a copy of the batch files. The following tables illustrate the types of data and crosswalks that must be constructed or programmed to integrate travel model output into ITHIM.

Table B.1 Data Dictionary for MTC Trip List

Name	Definition
hh_id	Unique household ID number
person_id	Unique person ID number
person_num	Person number unique to the household
tour_id	Individual tour number unique to the person
stop_id	Stop number unique to half tour
inbound	Inbound stop indicator
tour_purpose	Tour purpose, given the type of tour
orig_purpose	Purpose at the origin end of the trip
dest_purpose	Purpose at the destination end of the trip
orig_taz	Origin transportation analysis zone
orig_walk_segment	Walk to transit origin sub-zone (not located in space)
dest_taz	Destination transportation analysis zone
dest_walk_segment	Walk to transit destination sub-zone (not located in space)
depart_hour	Time of departure for the trip
trip_mode*	Travel mode for the trip
tour_mode	Primary (though not necessarily used) travel mode for the tour
tour_category	The type of tour for which this trip is a part

* Trip mode levels: Integer, 1 - Drive alone free; 2 - Drive alone pay; 3 - Shared ride 2 free; 4 - Shared ride 2 pay; 5 - Shared ride 3+ free; 6 - Shared ride 3+ pay; 7 - Walk; 8 - Bike; 9 - Walk to local bus; 10 - Walk to light rail or ferry; 11 - Walk to express bus; 12 - Walk to BART; 13 - Walk to commuter rail; 14 - Drive to local bus; 15 - Drive to light rail or ferry; 16 - Drive to express bus; 17 - Drive to BART; 18 - Drive to commuter rail (http://mtcgis.mtc.ca.gov/foswiki/Main/IndividualTrip)

Table B.2 Data Dictionary for ITHIM SKIM

Variables in Skim Output		
orig	ivtR_wTrnD	ddist_dTrnW
dest	wait_wTrnD	bike_bike
walk_walk	dtime_wTrnD	da_time
walk_wTrnW	ddist_wTrnD	da_dist
ivtB_wTrnW	walk_dTrnW	s2_time
ivtR_wTrnW	ivtB_dTrnW	s2_dist
wait_wTrnW	ivtR_dTrnW	s3_time
walk_wTrnD	wait_dTrnW	s3_dist
ivtB_wTrnD	dtime_dTrnW	

*First term is the ITHIM mode (walk=walk, ivtB=in vehicle time bus, ivtR=in vehicle time rail, wait=dwell time, dtime=drive time, ddist=drive distance, da=drive alone, s2=shared ride 2, s3=shared ride 3+.

** Second term is the mode from which it come (walk=walk, wTrnW=walk transit walk, wTrnD=walk transit drive, dTrnW=drive transit walk, bike=bike), the drive only modes have a second term describing the measure (time or dist).

Table B.3 Data Dictionary for Volume in Loaded Network by Vehicle Type

Variables used in Loaded Networks					
A (origin node)	VOLEA_SMT	VOLAM_HVT	VOLMD_TOT	VOLEV_DA	VOL24HR_S2
B (dest node)	VOLEA_HVT	VOLAM_TOT	VOLPM_DA	VOLEV_S2	VOL24HR_S3
DISTANCE (length of link)	VOLEA_TOT	VOLMD_DA	VOLPM_S2	VOLEV_S3	VOL24HR_SM
FT (facility type)	VOLAM_DA	VOLMD_S2	VOLPM_S3	VOLEV_SM	VOL24HR_HV
VOLEA_DA	VOLAM_S2	VOLMD_S3	VOLPM_SM	VOLEV_HV	VOL24HR_DAT
VOLEA_S2	VOLAM_S3	VOLMD_SM	VOLPM_HV	VOLEV_DAT	VOL24HR_S2T
VOLEA_S3	VOLAM_SM	VOLMD_HV	VOLPM_DAT	VOLEV_S2T	VOL24HR_S3T
VOLEA_SM	VOLAM_HV	VOLMD_DAT	VOLPM_S2T	VOLEV_S3T	VOL24HR_SMT
VOLEA_HV	VOLAM_DAT	VOLMD_S2T	VOLPM_S3T	VOLEV_SMT	VOL24HR_HVT
VOLEA_DAT	VOLAM_S2T	VOLMD_S3T	VOLPM_SMT	VOLEV_HVT	VOL24HR_TOT
VOLEA_S2T	VOLAM_S3T	VOLMD_SMT	VOLPM_HVT	VOLEV_TOT	VMT24HR
VOLEA_S3T	VOLAM_SMT	VOLMD_HVT	VOLPM_TOT	VOL24HR_DA	VHT24HR

* VOLXX refers to the volume for the time period (EA=3-6AM, AM=6-10AM, MD=10-3PM, PM=3-7PM, EV=7-3AM)

**Modes (DA=drive alone, S2=shared ride 2, S3=shared ride 3, SM=small/medium truck, HV=heavy truck, DAT=drive access transit)

Table B.4 MTC to ITHIM Facility Type Lookup

MTC Facility Type	ITHIM Facility Type
Freeway-to-freeway connector	Highway
Freeway	Highway
Expressway	Highway
Collector	Arterial
Freeway ramp	Highway
Dummy link	Local
Major arterial	Arterial
Special facility	None observed

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Table B.5 Examples of Selected Modes in MTC ABM and ITHIM

MTC Mode Name	ITHIM Mode
Drive alone free	Car
Drive alone pay	Car
Shared ride 2 free	Car
Shared ride 2 pay	Car
Shared ride 3+ free	Car
Shared ride 3+ pay	Car
Walk	Walk
Bike	Bike
Walk to local bus	Walk
Walk to light rail of ferry	Walk
Walk to express bus	Walk
Walk to BART	Walk
Walk to commuter rail	Walk
Drive to local bus	Car
Drive to light rail of ferry	Car
Drive to express bus	Car
Drive to BART	Car
Drive to commuter rail	Car

Appendix C. Race/Ethnicity Equity Analyses in California R/Shiny ITHIM

Background

Governmental agencies receiving federal funding are prohibited by federal statute to engage in discriminatory behavior based on race and ethnicity (Title VI of Civil Rights Act of 1964).[40] To assess compliance of their programs, policies, and activities, state and regional transportation agencies collect and analyze data on the demographics of travel, and report findings as part of developing and updating their regional and state transportation plans. Disparate treatment of and disproportionate burdens for racial minorities or low income populations - even when transportation policy or investments appear to be neutral - are subject to legal review.

Over several decades, accumulating scientific evidence show that neighborhoods in many communities face disproportionately high and adverse human health and environmental effects. In response, federal executive orders[41] were issued in the 1990s to promote environmental justice. They require a process that 1) identifies the presence of minority populations, low-income populations, or Indian tribes; 2) provides public participation; 3) analyzes quantitative information (including public health data), and 4) considers alternatives and mitigation of hazards.

ITHIM is well-suited to assess whether health benefits or burdens in transportation have disproportionate health burdens in populations defined by race/ethnicity, income, and other dimensions of social disadvantage. The California R/Shiny version of ITHIM facilitates this type of analysis by providing statewide and regional race/ethnicity-specific calibration data. The methods can be extended to other dimensions of health equity, such as income, which are still in development.

This documentation explains how the R/Shiny version of California ITHIM can be used to carry out analyses of health equity for non-Hispanic subgroups of Whites, African Americans, and Asian and Pacific Islanders, and for Latinos of any race. These are subgroups for which statistically reliable data were available across travel and health data sources.

Methods

California ITHIM has a built-in mechanism to examine the gender and age equity associated with scenarios projected between 2010 and 2050. This is achieved by age and gender stratification of:

- Active travel
- Dose-response functions
- Population projections
- Projected changes in disease rates, and
- Global burden of disease.

These five items are the components of the comparative risk assessment methodology, which are discussed in Chapter 1 of the California ITHIM User's Guide and Technical Manual.[42] To add another dimension of equity, these five components must be made specific to population

subgroups. For the analysis of racial/ethnicity equity, this is achieved by additional stratification by race/ethnicity and statistical adjustments. An overview of the data processing steps (Figure 1) to generate race/ethnicity-specific calibration data is presented below.

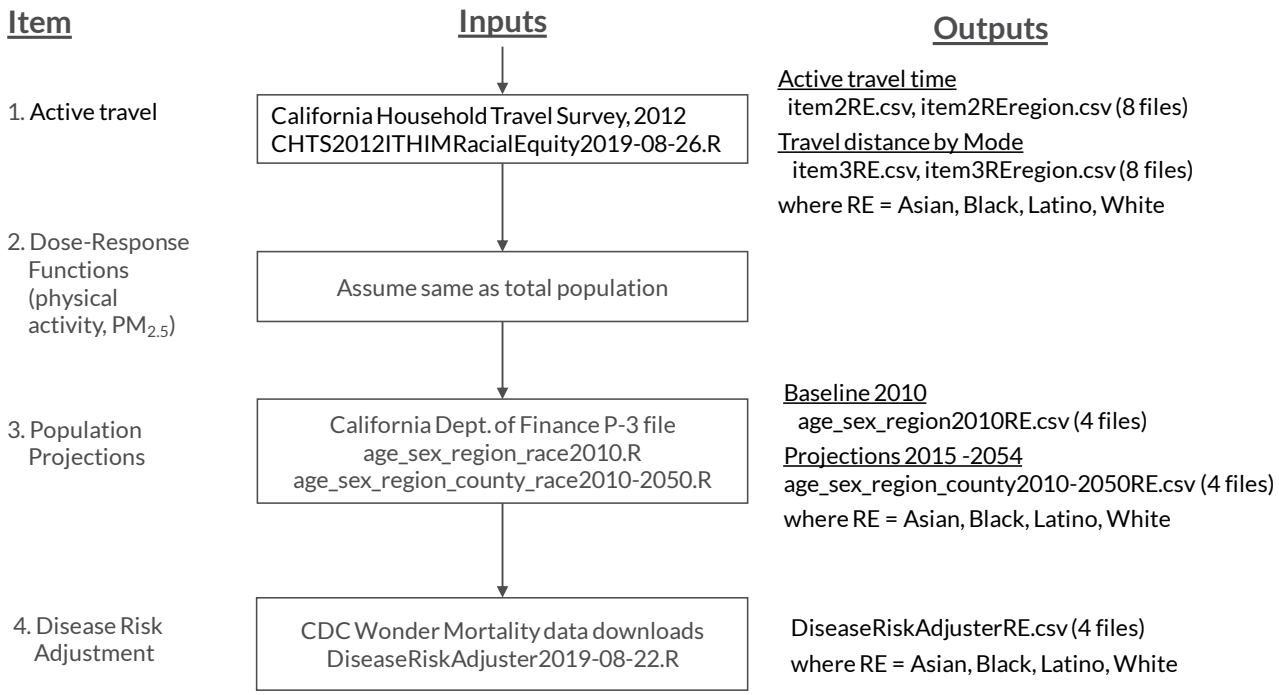


Figure 1. Data Processing Steps for Race/Ethnicity Versions of California R/Shiny ITHIM

Baseline Calibration Data

Active and Motorized Travel

The California Household Travel Survey 2012 was the source of calibration data and the baseline scenario for active (walking, cycling) and motorized travel (cars, motorcycle, rail, and bus). The survey allowed respondents to self-identify up to three races, and, as a separate question, their ethnicity as being Hispanic or not. Each of the three race fields were closed-ended and listed race as: White, Black or African American; American Indian or Alaska Native; Asian (Asian Indian, Japanese, Chinese, Korean, Filipino, Vietnamese); Native Hawaiian or Pacific Islander (Guamanian, Samoan, Fijian); and Other (specify). Of 109,113 respondents, 11,489 (10.5%) selected "Other" and provided a short text description. The text strings were reviewed and classified by race and ethnicity, based on national origin. For example, respondents stating Mexican, Mexican-American, Peruvian, or Puerto Rican were classified as Latinos. Respondents stating Belgian, Middle Eastern, Portuguese, etc. were classified as White. After reclassification in mutually exclusive categories, 2867 respondents (2.6%) who stated "did not know" or refused to answer had missing race/ethnicity.

To create a mutually exclusive classification of race/ethnicity, Latino of any race was created from a positive response to the survey's original Hispanic flag field and Hispanic from "Other." Native Hawaiian and Pacific Islanders were combined into the Asian category to correspond to

race/ethnicity in mortality data. The final race/ethnicity classification for baseline travel in the equity analysis was: non-Hispanic Asians, non-Hispanic Blacks, Latinos, and non-Hispanic Whites. American Indians/Alaskan Natives were less than 1% of survey respondents and did not have a sufficient sample size to provide statistically reliable stratifications by travel mode.

The R program (CHTS2012ITHIM2016-03-26.R), originally used to generate statewide and regional baseline travel, was modified (CHTS2012ITHIMRacialEquity2019-08-26.R) to stratify travel distances and times by race/ethnicity. Race/ethnicity-specific travel distance by mode included walk, bicycle, car-driver, car-passenger, bus, rail, motorcycle, and race/ethnicity-specific active travel times were stratified by age and gender.

Statewide and regional race/ethnicity-specific outputs of the R program were manually reformatted in Excel and cut-and-pasted into the R/Shiny calibration data files for travel distances by mode (Baseline2010 in the \tool_files\default_narratives_2019_07_10.csv) and active travel times (\tool_files\ATmean_min_week_age_sex_baseline.csv).

Coefficient of variation of active travel time was not recalculated for each race/ethnicity and it is assumed that the shape of the distributions follow that of the overall population.

Dose Response Functions

Dose response gradients ($\Delta RR/\Delta Exposure$ in physical activity and ambient $PM_{2.5}$ concentration) were developed from meta-analyses in which variables such as age, sex, race, education, smoking, and obesity were covariates. Several of the dose-response coefficients in ITHIM are age- and sex-dependent (colon cancer, depression), but none are race/ethnicity specific. No adjustments for race/ethnicity were made in the dose-response for physical activity or $PM_{2.5}$ pathways. For road traffic injuries, the risk measure is distance traveled by striking and victim vehicle/conveyance. This considers miles traveled only within the race/ethnicity subpopulation.

For several chronic diseases (dementia, depression, colon cancer, and breast cancer), the dose-response function incorporated non-travel physical activity. In addition to the assumption that non-travel physical activity does not change over time, race/ethnicity specific non-travel physical activity distributions were assumed to follow that of the overall population.

Population Projections

The California Department of Finance projects county populations by age, sex and race/ethnicity for major subgroups Non-Hispanic Whites, non-Hispanic Blacks, non-Hispanic American Indian or Alaska Native, non-Hispanic Asian, non-Hispanic Native Hawaiian or Pacific Islander, Multiracial, and Hispanic of any race).[11] An R program (age_sex_region_county_race2010-2050.R) aggregated population counts in 5 calendar year intervals from 2015 to 2054 and produced an output calibration file (age_sex_region_county2010-2050.csv). To facilitate correspondence with race/ethnicity in mortality data, Asians and Native Hawaiians/Pacific Islanders were combined into a single group.

Projected Change in Disease Rates

California ITHIM projects the future burden of disease by accounting for changes in age- and sex-

specific disease rates from 2010 to 2050 for major chronic diseases and road traffic injuries. Data were not available to stratify the annual percent change by race/ethnicity. It is assumed that the change in rates with time are the same for the different race/ethnicities.

Burden of Disease

In California ITHIM, the projected burden of disease and injury is the product of the projected population, the baseline mortality or DALY rate (per baseline population), and the annual percent change in disease-specific mortality rate (APC). For the *i*th disease, the burden (BD) is:

$$BD_i = Population \times Mortality\ (or\ DALY)\ Rate_i \times APC_i$$

Mortality and DALY rates are expressed in terms of deaths or DALYs per 100,000 population. To render race/ethnicity-specific burdens of disease, the population is that of the statewide or regional specific to a race/ethnicity group (e.g. Asian, Black, Latino, White) rather than the population that combines all race/ethnicities (total population). The mortality rate, which is broken down by age (j) and gender (k), must reflect that of the specific race/ethnicity group.

California ITHIM projects the disease-age-sex and race/ethnicity-specific burden of disease by adjusting the disease-specific rates of death and DALY rates of the entire population by a constant that is the age-sex-disease-specific mortality rate ratio of the race/ethnicity group of interest to that of the entire population:

$$Disease\ Risk\ Adjustment(Adj)_{ijk} = \frac{Death\ Rate(ijk)_{specific\ group}}{Death\ Rate(ijk)_{total\ population}}$$

$$BD_{ijkl} = Population_{jkl} \times Mortality\ (or\ DALY)\ Rate_{ijk.} \times Adj_{ijkl} \times APC_{ijk}$$

Thirteen ITHIM disease categories are stratified by 2 genders, 8 age groups, 6 geographical areas (1248 cells), and 1 disease (acute respiratory infections in children aged 0 to 4 years) are stratified by 2 genders and 6 geographies (12 cells). The disease adjustment file for each race-ethnicity thus has 1260 cells.

To create the numerator and the denominator rates in the disease risk adjustment above, age-sex-disease- and county-specific mortality rates were created for each of the four race/ethnicities from data downloaded from CDC Wonder's interface (84 files).[43] The data included counts of deaths for specific diseases and population broken down by age, sex, race/ethnicity, and geography (county or State of California). With minor differences, the diagnostic categories in ITHIM as defined by ICD codes corresponded to those CDC Wonder (Table 1, page 6).

Race/ethnicity was classified in CDC Wonder as non-Hispanic Whites, non-Hispanic Blacks, non-Hispanic Asians, and Hispanics (Latinos) of any race. An R program (DiseaseRiskAdjuster2019-08-22.R) aggregated counts by county to the regions defined in the ITHIM application.[42,p.20] The program also reconciled differences in age groupings. WONDER and ITHIM age groupings corresponded exactly for 0-4 and 5-14 years. For WONDER groupings (15-24, 25-34, 35-44, 54-65, 65-74, 75-84, 85+), midpoint counts were aggregated to or from adjacent categories (e.g. $deaths_{15\text{-}29}$ [ITHIM] = $deaths_{15\text{-}24}$ + ½*$deaths_{25\text{-}34}$ [WONDER]). The R program calculated the mortality death rate for the entire California population (denominator in adjustment factor) and

the race/ethnicity-specific numerate rate.

To maintain confidentially, CDC WONDER suppresses reporting when the age-sex-race/ethnicity-disease cells have less than 10 deaths. When this occurred the adjustment factor was set to 1. Because chronic disease mortality is generally quite low in ages less than 45 years (Table 2, pages 7-10), data suppression may diminish the validity of adjustment if it common at older ages.

For each major race/ethnicity at the California statewide geography, suppression affected primarily ages under 30 years. However, for regions, data suppression was more prevalent in ages between 45 and 60. For regional analyses, one should consult Table 2 to assess whether data suppression may result in only small differences between the burden of disease of the race/ethnicity group and that of the general population.

By adjusting the overall disease rates by a vector of constants, it is possible to genericize the adjustment of the disease burden for any dimension of equity. For example, if the overall population can be stratified into income or poverty quartiles and mortality rates are known for each income level, it is possible to adjust the overall burden of disease by income-specific adjustment factor. Likewise, baseline calibration of travel patterns would also be stratified by income levels.

Scenario Data

Several of the built-in scenarios may be used in equity analyses. These include those that multiply 2010 baseline levels of walking, cycling, and/or transit or specify absolute amounts of physical activity time for walking and cycling (Caltrans Strategic Management, Plan, California Air Resources Board Scoping Plan Update, Baseline Multiples, Fixed Time, U.S. Surgeon General).

Users may also create use their own travel data or both baseline and scenarios specific to race/ethnic groups. Activity-based travel demand models of metropolitan planning organizations or academic centers may be source of these data.

Table 1. Correspondence Between Diagnostic Categories for California ITHIM and CDC Wonder

Title in ITHIM	ITHIM (ICD-10)	CDC Wonder
Colon cancers	C18	C18
Breast Cancer	C50	C50
Cardiovascular Disease		
Hypertensive heart disease	I11	I11
Ischemic heart disease	I20-I25	I20-I25
Cerebrovascular disease	I60-I63, I65-I67, I69.0, I69.1, I69.2, I69.3	I60-I69
Alzheimer and other dementias	F01-F03, G30-G31	F01,F03, G30-G31
Diabetes mellitus	E10-E13	E10, E11, E12, E13
Depression (major depressive disorders)	F32-F33	F32-F33
Road Injuries	V01-V04, V06, V09, V10-V19, V20-V29, V30-V79, V87.2-V87.3, V80, V82	V01-V04, V06, V09, V10-V19, V20-V29, V30-V79, V87.2-V87.3, V80, V82
Cardio-respiratory: a. Lower respiratory infections, upper respiratory infections b. Same as cardiovascular above + inflammatory heart diseases c. Chronic obstructive pulmonary disease, Asthma, Other respiratory diseases	 J09-J11, J13, J14, J12.1, J12, J15-J22, J85, P23, J00-J06 I11, I20-I25, I60-I63 I65-I67, I69.0, I69.1, I69.2, I69.3, I40, I42 J40-J44, J45-45, J47, J30-J39, J66-J68, J70, J82, J92, J93.0, J93.1, J95, J98.0, J98.4, J98.5, J98.6, J98.8	 J00-06, J09-18, J20-J22, J85 I40, I42 J30-J39, J40-J44, J45-45, J47, J66-J68, J70, J82, J92, J93.0, J93.1, J98.0, J98.4, J98.5, J98.6, J98.8
Lung cancer (Trachea, bronchus and lung)	C33-C34	C33-C34
Acute Respiratory Infections (children < 5 years)	J09-J11, J13, J14, J12.1, J12, J15-J22, J85, P23, J00-J06	J00-06, J09-18, J20-J22, J85

Table 2. Asian: Age-Sex Groups Without Suppressed Data for Disease-Specific Adjustments by Race/Ethnicity and Region

Region	Acute resp infections	All Causes	Breast Cancer	Colon Cancer	Dementia	Depression	Diabetes	Hypertensive Heart Disease	Inflammatory Heart Disease	Ischemic Heart Disease	Lung Cancer	Respiratory diseases	Road Traffic Injuries	Stroke
Cali-fornia	None	M/F: All	30-80+	M/F: 30-80+	M/F: 60-80+	None	M/F: 45-80+	M:30-80+ F:45-80+	M:15-80+ F:45-80+	M/F: 30-80+	M/F: 45-80+	M:30-80+ F:45-80+	M: 5-80+ F:15-80+	M/F: 30-80+
Sacra-mento	None	M/F: 15-80+	45-69	M/F: 80+	M/F: 80+	None	F: 80+	None	None	M:15-80+ F:60-80+	M:45-80+ F:60-80+	M/F: 70-80+	None	M/F: 45-80+
San Diego	None	M:All F:15-80+	45-79	M:45-80+ F:80+	M/F: 80+	None	F: 80+	None	None	M:15-80+ F:60-80+	M/F: 45-80+	M:60-80+ F: 80+	None	M/F: 45-80+
SJV	None	M/F: 15-80+	45-59	None	F: 80+	None	None	None	None	M:15-80+ F:60-80+	M:60-80+ F:60-69	M:70-80+	None	M:45-80+ F:60-80+
SF Bay	None	M/F: All	45-80+	M/F: 45-80+	M/F: 80+	None	M:60-80+ F:70-80+	None	None	M/F: 45-80+	M/F: 45-80+	M/F: 70-80+	None	M/F: 45-80+
So. Cal	None	M/F: All	45-80+	M/F: 45-80+	M/F: 70-80+	None	M:45-80+ F:60-80+	F:80+	M:45-80+ F:60-80+	M:30-80+ F:45-80+	M/F: 45-80+	M:45-80+ F:60-80+	M: 15-80+ F:15-29, 60-80+	M/F: 45-80+

Table 2. Black: Age-Sex Groups Without Suppressed Data for Disease-Specific Adjustments by Race/Ethnicity and Region

Region	Acute resp infections	All Causes	Breast Cancer	Colon Cancer	Dementia	Depression	Diabetes	Hypertensive Heart Disease	Inflammatory Heart Disease	Ischemic Heart Disease	Lung Cancer	Respiratory diseases	Road Traffic Injuries	Stroke
Cali-fornia	None	M/F: All	30-80+	M/F: 45-80+	M/F: 60-80+	None	M/F: 30-80+	M/F: 30-80+	M/F: 15-80+	M/F: 30-80+	M/F: 45-80+	M: 5-80+ F:30-80+	M/F: 5-79	M/F: 30-80+
Sacra-mento	None	M: 5-80+ F: 15-80+	45-79	M: None F:60-79	M/F: 80+	None	M:45-69 F:45-79	None	M: 45-59 F:None	M/F: 45-80+	M: 45-79 F:45-80+	M: 60-80+ F: 45-80+	None	M/F: 45-80+
San Diego	None	M/F: 5-80+	45-79	M:60-69 F:None	M: 80+ F: 70-80+	None	M: 60-69	None	M:45-69 F:None	M/F: 45-80+	M: 45-79 F: 60-79	M/F: 60-80+ F: 80+	None	M/F: 45-80+
SJV	None	M: 0-4, 15-80+ F: 15-80+	None	None	F: 80+	None	None	None	None	M: 45-80+ F: 60-80+	M: 60-79 F:60-69	M: 60-80+	None	M: None F:70-80+
SF Bay	None	M: 5-80+ F: 0-4, 15-80+	45-80+	M/F: 60-80+	M/F: 70-80+	None	M:60-69 F: 60-80+	None	M: 45-80+ F: 80+	M/F: 45-80+	M/F: 45-80+	M: 60-80+ F: 45-80+	None	M/F: 45-80+
So. Cal	None	M/F: All	30-80+	M/F:045-80+	M/F: 70-80+	None	M/F: 45-80+	M: 45-80+ F: 60-80+	M: 15-80+ F: 30-80+	M:30-80+ F: 45-80+	M/F: 45-80+	M: 30-80+ F:45-80+	M: 15-69 F:15-29, 45-69	M/F: 45-80+

Table 2. Latino: Age-Sex Groups Without Suppressed Data for Disease-Specific Adjustments by Race/Ethnicity and Region

Region	Acute resp infections	All Causes	Breast Cancer	Colon Cancer	Dementia	Depression	Diabetes	Hypertensive Heart Disease	Inflammatory Heart Disease	Ischemic Heart Disease	Lung Cancer	Respiratory diseases	Road Traffic Injuries	Stroke
Cali-fornia	M/F: 0-4	M/F: All	30-80+	M/F: 30-80+	M/F: 45-80+	None	M/F: 30-80+	M/F: 30-80+	M/F: 15-80+	M: 15-80+ F:30-80+	M/F: 30-80+	M:All F:0-4, 15-80+	M/F: 5-80+	M: 15-80+ F:All
Sacra-mento	None	M: All F: 0-4, 15-80+	45-69	M/F: None	M/F: 80+	None	M:60-69 F:None	None	None	M: 45-80+ F:60-80+	M: 45-80+ F:60-80+	M: 80+ F: 70-80+	F:70-79	M/F: 60-80+
San Diego	None	M/F: All	45-80+	M:45-79 F: 45-80+	M: 70-80+ F: 80+	None	M: 45-80+ F: 60-80+	M:45-69 F:None	M:70-80+ F:80+	M/F: 45-80+	M/F: 45-80+	M/F: 60-80+	M: 60-80+ F: 60-79	M/F: 45-80+
SJV	None	M/F: All	45-79	M:45-80+ F: None	M/F: 80+	None	M: 60-80+ F: 70-80+	None	None	M/F: 45-80+	M: 45-80+ F: 60-79	M/F: 70-80+	M:45-79	M/F: 45-80+
SF Bay	None	M/F: All	45-80+	M: 60-79 F:80+	M/F: 80+	None	M: 45-80+ F: 60-80+	M: 45-59, 70-80+ F: 80+	None	M/F: 45-80+	M/F: 60-80+	M: 60-80+ F: 70-80+	M: 70-79 F: 70-80+	M/F: 45-80+
So. Cal	None	M/F: All	30-80+	M: 30-80+ M: 45-80+	M: 70-80+ F: 60-80+	None	M/F: 45-80+	M: 30-80+ F: 45-80+	M: 15-80+ F: 30-80+	M:30-80+ F: 45-80+	M: 30-80+ F: 45-80+	M: 30-80+ F:45-80+	M/F: 30-80+	M: 30-80+ F:15-80+

Table 2. White: Age-Sex Groups Without Suppressed Data for Disease-Specific Adjustments by Race/Ethnicity and Region

Region	Acute resp infections	All Causes	Breast Cancer	Colon Cancer	Dementia	Depression	Diabetes	Hypertensive Heart Disease	Inflammatory Heart Disease	Ischemic Heart Disease	Lung Cancer	Respiratory diseases	Road Traffic Injuries	Stroke
Cali-fornia	M: 0-4 F:none	M/F: All	30-80+	M/F: 30-80+	M/F: 45-80+	M/F: 80+	M/F: 30-80+	M: 15-80+ F:30-80+	M/F: 15-80+	M: 15-80+ F:30-80+	M: 30-80+ F:45-80+	M/F: 15-80+	M/F: 5-80+	M/F: 15-80+
Sacra-mento	None	M/F: All	45-80+	M/F: 45-80+	M/F: 70-80+	None	M/F: 45-80+	None	M/F: 45-80+	M/F: 45-80+	M/F: 45-80+	M/F: 45-80+	M:15-69	M/F: 45-80+
San Diego	None	M/F: All	45-80+	M/F: 45-80+	M/F: 60-80+	None	M: 45-80+ F: 60-80+	M/F: 80+	M/F: 45-80+	M: 30-80+ F:45-80+	M/F: 45-80+	M/F: 45-80+	M: 15-79 F: 45-59	M/F: 45-80+
SJV	None	M: All F:5-80+	45-80+	M/F: 45-80+	M/F: 70-80+	None	M/F: 60-80+	None	M/F: 45-80+	M/F: 45-80+	M/F: 45-80+	M/F: 45-80+	M: 15-79 F: 30-44	M/F: 45-80+
SF Bay	None	M: All F:5-80+	45-80+	M/F: 45-80+	M/F: 60-80+	None	M: 60-80+ F: 45-80+	M: None F: 80+	M: 45-80+ F:60-80+	M/F: 45-80+	M/F: 45-80+	M/F: 45-80+	M: 15-69 F: None	M/F: 45-80+
So. Cal	None	M/F: All	30-80+	M/F: 45-80+	M/F: 60-80+	None	M/F: 45-80+	M: 70-80+ F: 80+	M: 30-80+ F: 45-80+	M:30-80+ F: 45-80+	M/F: 45-80+	M/F: 45-80+	M/F: 15-80+	M: 30-80+ F:15-80+

Framework for Health Equity Analysis

There are many frameworks used by different disciplines to explore equity and health equity. Even within disciplines, equity may have different dimensions. In transportation equity may consider, mode equity, urban/suburban/rural time/financial burdens, civil rights, and environmental justice.[44] Public health framing examines differences in social determinants of health and in health outcomes among population subgroups that are avoidable and unjust.[45]

It is useful to explore health equity by posing a series of questions, taking into account baseline metrics and scenario-based changes in travel and health. These can be compared to each race/ethnicity subgroup's own baseline and changes in other race/ethnic groups:

- How do the baseline travel patterns differ by race/ethnic groups?
- What is the baseline burden of disease for each race/ethnicity group?
- How do the baseline burdens compare among the different groups?
- Does the scenario increase or decrease the burden of disease/injury for a specific race/ethnicity group?
    - Is this change meaningful in the context of the group's overall disease/injury burden?
- For a given scenario, how does the change in burden of disease/injury compare between the different race/ethnicity groups?
    - If all groups benefit, do some groups benefit more than others?
    - Are these groups the ones with the greatest baseline burden?

Difference Within Differences

Several of the questions above relate to comparing changes in the burden of disease between race/ethnic groups. These changes themselves are the result of differences in baseline and scenario travel patterns. These differences are nested within the race/ethnicity differences, hence an analytic framework called "differences within differences."

Because the population size and burden of disease varies by group, we can compare these changes in the burden of disease across all racial/ethnic groups by expressing the health benefits (or harms) on a common population basis such as deaths or DALYs per 100,000 population. In the ITHIM Tool (RunITHIM), Table 1 (High Detail) provides population counts for baseline and scenario, so users can create metrics with a common population basis.

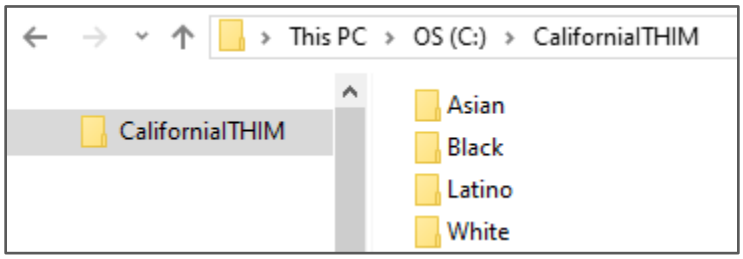
Running Equity Analyses in California ITHIM

Analyses of race/ethnicity are currently available in the development environment of California R/Shiny ITHIM. That is, they must be run from user's desktop/laptop computers rather from the public website. To create the desktop computer development environment, users must:

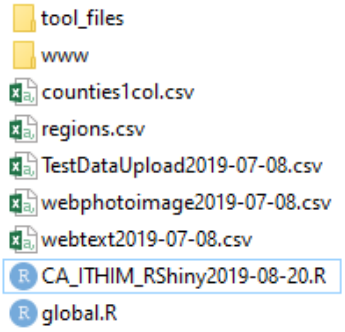
1. Download and install R (https://cran.cnr.berkeley.edu/)
2. Download and install RStudio (https://www.rstudio.com/products/rstudio/download/)
3. Within RStudio, install the following R packages: shiny, digest, markdown, grid, and png.
4. Download the race/ethnicity files (CaliforniaITHIM_RaceEth.zip) at R & Shiny Code at the User

Support page of California ITHIM (https://ww2.arb.ca.gov/ITHIM/#UserSupport)

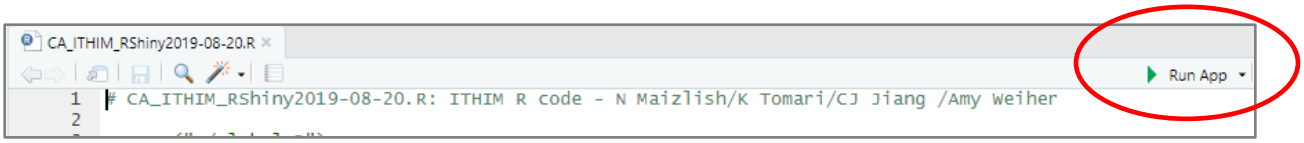
5. Unzip the file folders and place them on your desktop/laptop/tablet. They should look like the following:



6. To conduct an analysis of a single race/ethnic group, open the corresponding folder (e.g. Asian):



7. double click CA_ITHIM_RShiny2019-08-20.R
8. click on runApp in the upper right corner of RStudio source code tab:



9. The operation of race/ethnicity versions of California ITHIM is exactly the same as that of the web-based version. Users may use the built-in scenarios with the default 2010 baseline data for each race/ethnic group, or provide their own baseline/business-as-usual and scenario data via the User Upload option in the Scenarios selection.

Chapter References

1. Office of Civil Rights. *Title VI of the Civil Rights Act of 1964*. Washington, DC: Federal Transit Administation; 2019.https://www.transit.dot.gov/title6. Accessed September 6, 2019.
2. Office of Planning & Environment. *Environmental Justice*. Washington, DC: Federal Transit Administation; 2019.https://www.transit.dot.gov/regulations-and-guidance/environmental-programs/environmental-justice/environmental-justice. Accessed September 6, 2019.
3. Maizlish N, Tomar T, London L, Jiang C, Weiher A. *User's Guide and Technical Manual: California R/Shiny Version*. Davis, CA: University of California; 2019. https://ww2.arb.ca.gov/ITHIM/ITHIM_manual_draft.pdf. Accessed September 7, 2019.
4. Demographic Research Unit. *P-3: State and County Projections Dataset*. Sacramento, CA: California Department of Finance; 2019.http://www.dof.ca.gov/Forecasting/Demographics/Projections/P3_Complete.zip. Accessed August 9, 2019.
5. Centers for Disease Control and Prevention, National Center for Health Statistics. *Underlying Cause of Death, 1999-2017 on CDC WONDER Online Database, released December, 2018. Data are from the Multiple Cause of Death Files, 2008-2012*. Atlanta, GA: Centers for Disease Control and Prevention; 2019.http://wonder.cdc.gov/ucd-icd10.html. Accessed Aug 21, 2019.
11. Demographic Research Unit. *P-3: State and County Projections Dataset*. Sacramento, CA: California Department of Finance; 2019.http://www.dof.ca.gov/Forecasting/Demographics/Projections/P3_Complete.zip. Accessed August 9, 2019.
40. Office of Civil Rights. *Title VI of the Civil Rights Act of 1964*. Washington, DC: Federal Transit Administation; 2019.https://www.transit.dot.gov/title6. Accessed September 6, 2019.
41. Office of Planning & Environment. *Environmental Justice*. Washington, DC: Federal Transit Administation; 2019.https://www.transit.dot.gov/regulations-and-guidance/environmental-programs/environmental-justice/environmental-justice. Accessed September 6, 2019.
42. Maizlish N, Tomar T, London L, Jiang C, Weiher A. *User's Guide and Technical Manual: California R/Shiny Version*. Davis, CA: University of California; 2019. https://ww2.arb.ca.gov/ITHIM/ITHIM_manual_draft.pdf. Accessed September 7, 2019.
43. Centers for Disease Control and Prevention, National Center for Health Statistics. *Underlying Cause of Death, 1999-2017 on CDC WONDER Online Database, released December, 2018. Data are from the Multiple Cause of Death Files, 2008-2012*. Atlanta, GA: Centers for Disease Control and Prevention; 2019.http://wonder.cdc.gov/ucd-icd10.html. Accessed Aug 21, 2019.
44. Committee on Equity Implications of Evolving Transportation Finance Mechanisms. *Equity of Evolving Transportation Finance Mechanisms. Special Report 303*. Washington, DC: Transportation Research Board; 2011.http://onlinepubs.trb.org/onlinepubs/sr/sr303.pdf. Accessed September 8, 2019.
45. World Health Organization. *Health Impact Assessment Glossary of Terms: Health Inequality and Inequity*. Geneva, Switzerland: World Health Organization; 2017.https://www.who.int/hia/about/glos/en/index1.html. Accessed September 8, 2019.

Appendix D. Update of California ITHIM Road Traffic Injury Calibration Data, 2011-2015

Background/Overview

Spreadsheet versions of the Integrated Transport and Health Impact Model (ITHIM version. 12/12/2016) used road traffic injury (RTI) data compiled from the Statewide Integrated Traffic Reporting System (SWITRS) for severe and fatal injuries occurring in California from 2006 to 2010. This document describes the process for creating updated calibration data for SWITRS data for injuries occurring from 2011 to 2015 for both the spreadsheet and R/Shiny versions of ITHIM. Chapter 1 of the California ITHIM *User's Guide and Technical Manual*, pages 7-8, describes the methods for characterizing risk of road traffic injury in California ITHIM.

The process of creating the 2006-2010 Calibration file for spreadsheet ITHIM involved 6 major steps using four software applications: , MS Access , ArcGIS, SAS, and Excel. The process of creating an updated RTI data file was accomplished in the same 6 major processing steps with mostly the same software applications (R, ArcGIS, SAS, and Excel). In general, the update required small modifications of the preexisting applications and processing steps, so that that the SAS code (>1000 lines) previously developed by the California Department of Public Health could be recycled, saving much time and effort. The major processing steps are presented below and illustrated in Figure 1:

1. Acquire SWITRS Data, 2011-2015
2. Spatially join collisions with roadway segments to assign roadway facility type (ArcGIS)
3. Assign each injury a victim mode of travel and a striking vehicle mode of travel (SAS)
4. Construct an injury matrix in a standardized format (SAS)
5. Input the matrix into the spreadsheet ITHIM (Excel)
6. Reformat the matrices for R/Shiny ITHIM (Excel)

Methods

1. Acquire SWITRS Data, 2011-2015

SWITRS data are made publically available by the University of California Safe Transportation Research and Education Center (SafeTREC) through its Traffic Injury Mapping System, TIMS, at https://safetrec.berkeley.edu/tools/transportation-injury-mapping-system-tims. One must establish an account in order to access free data downloads. TIMS offers a SWITRS Query & Map option to access data in an interactive tool. Figure 2 displays a sequence of screenshots of the process of downloading collision, party, and victim files for specific counties in California. Users should download the SWITRS codebook that describes the file layouts, variable names, definitions, and coding levels (https://tims.berkeley.edu/help/SWITRS.php#Codebook).

Figure 1. Overview of Updating the Road Traffic Injury Calibration Data

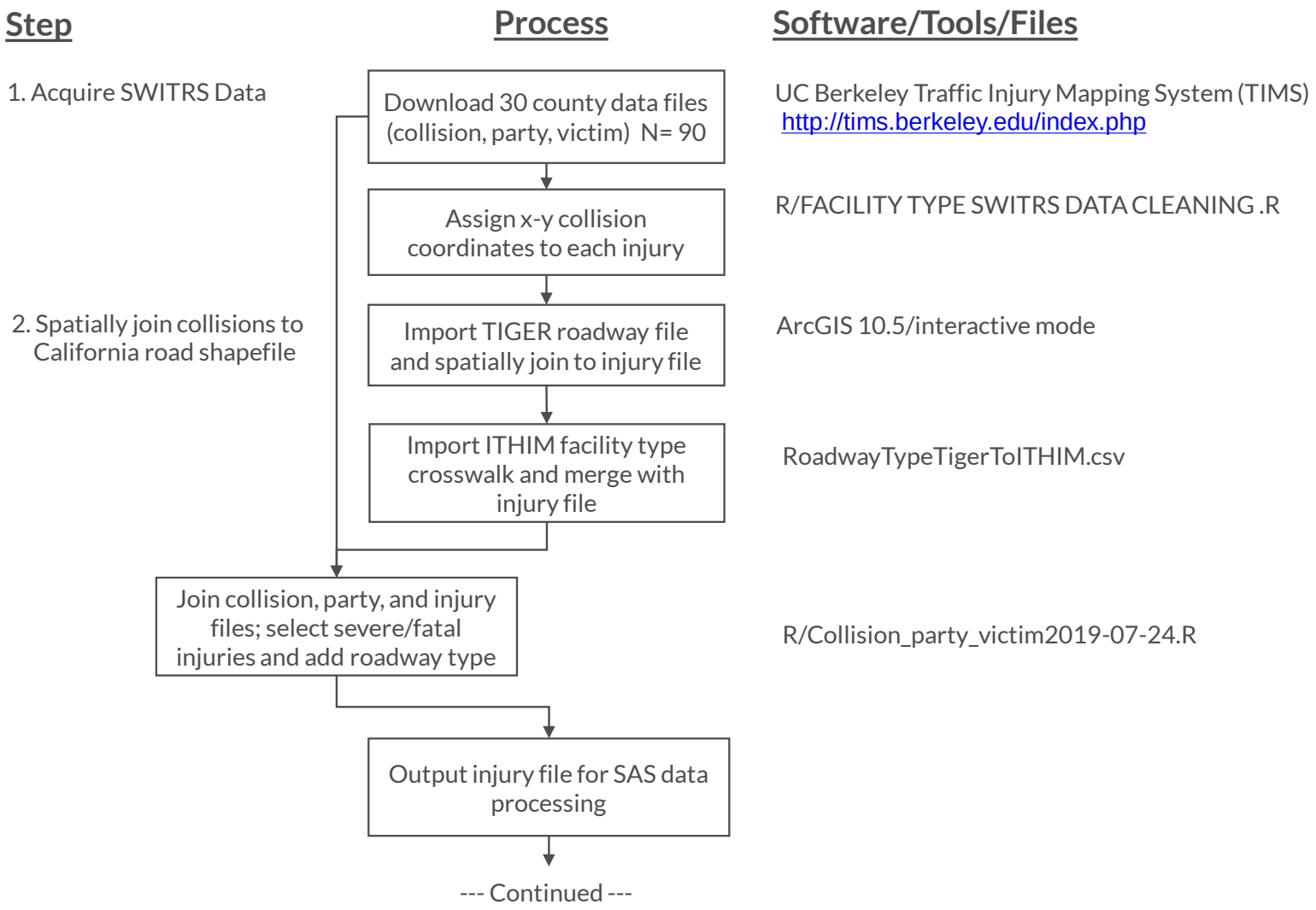


Figure 1. Overview of Updating the Road Traffic Injury Calibration Data

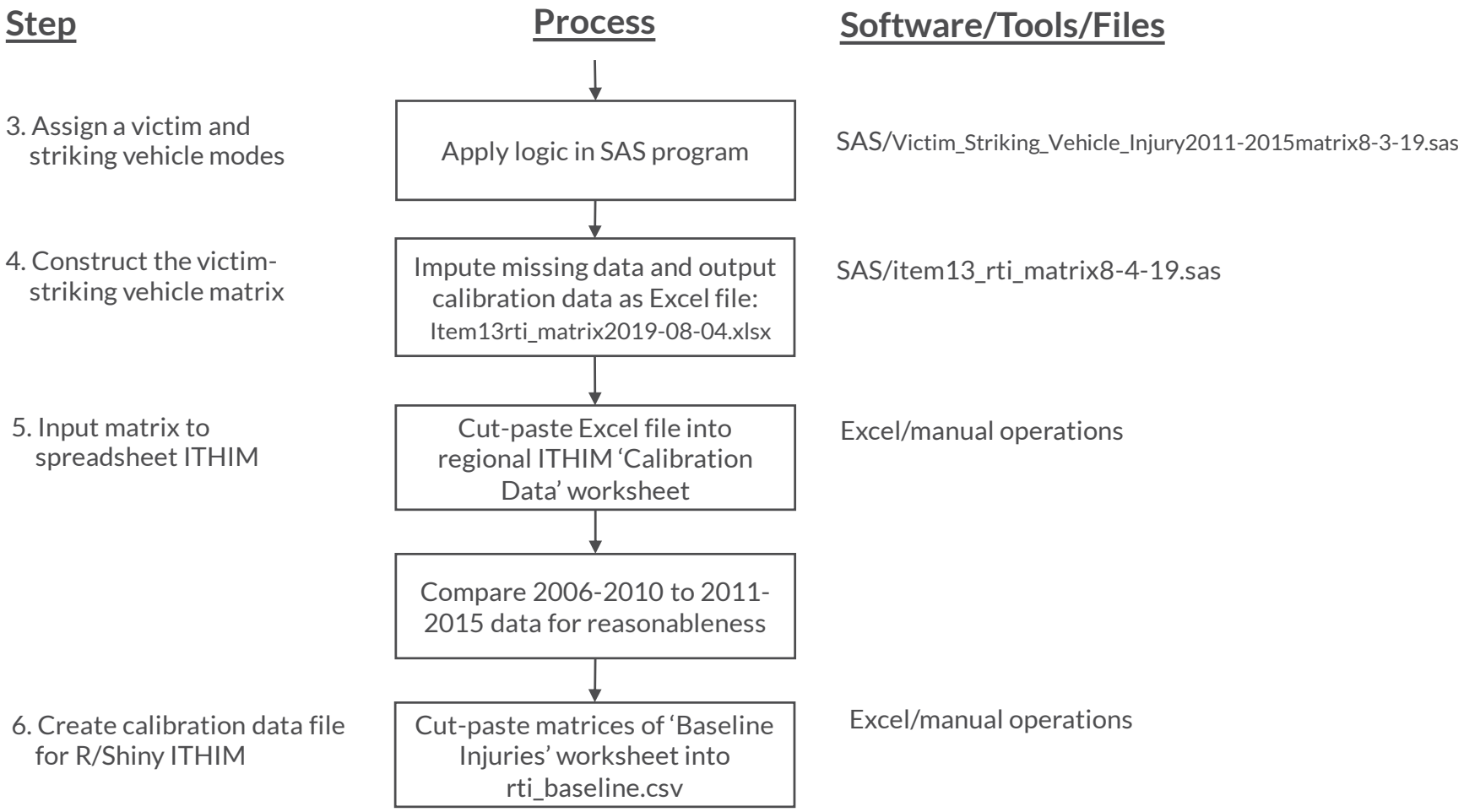
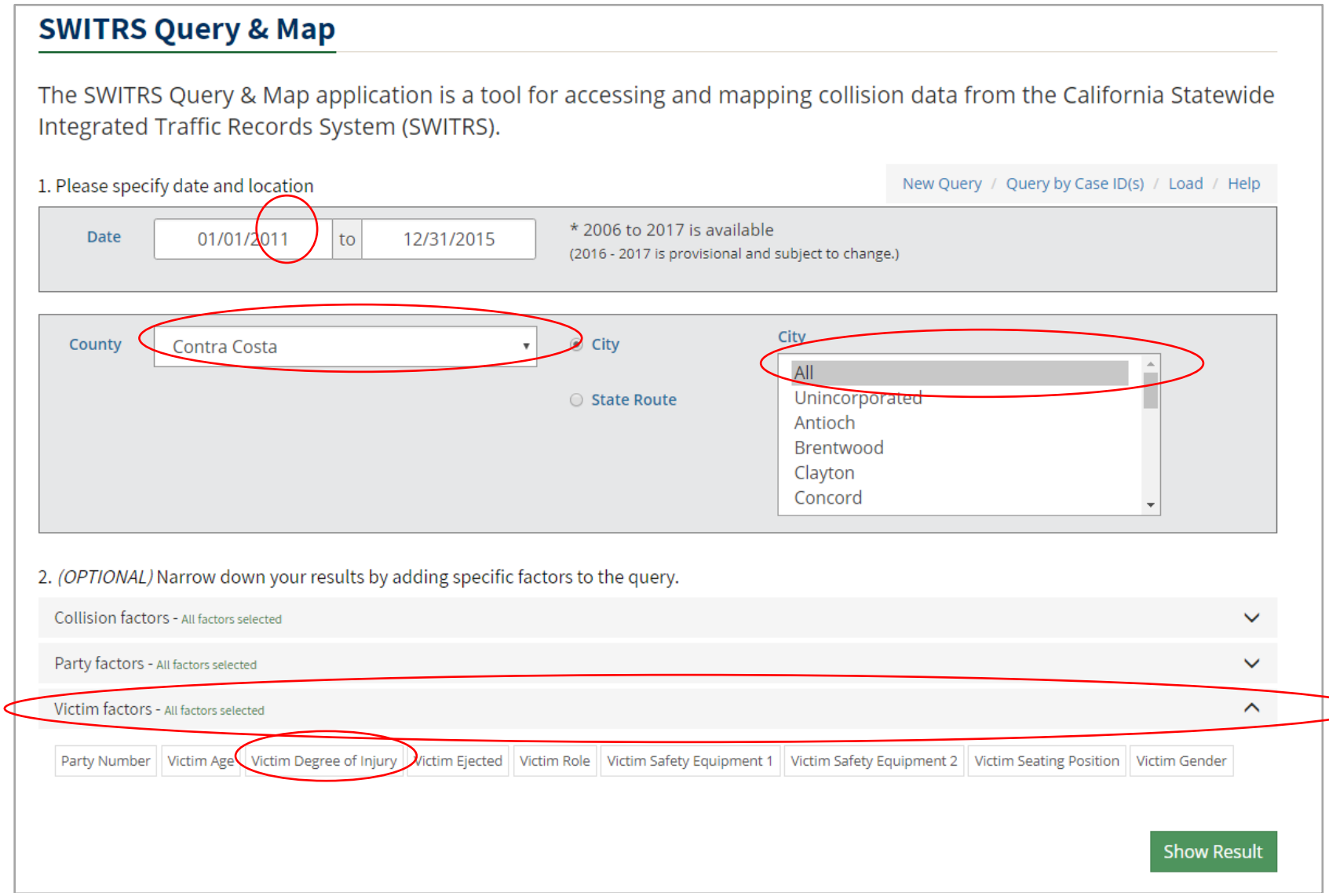
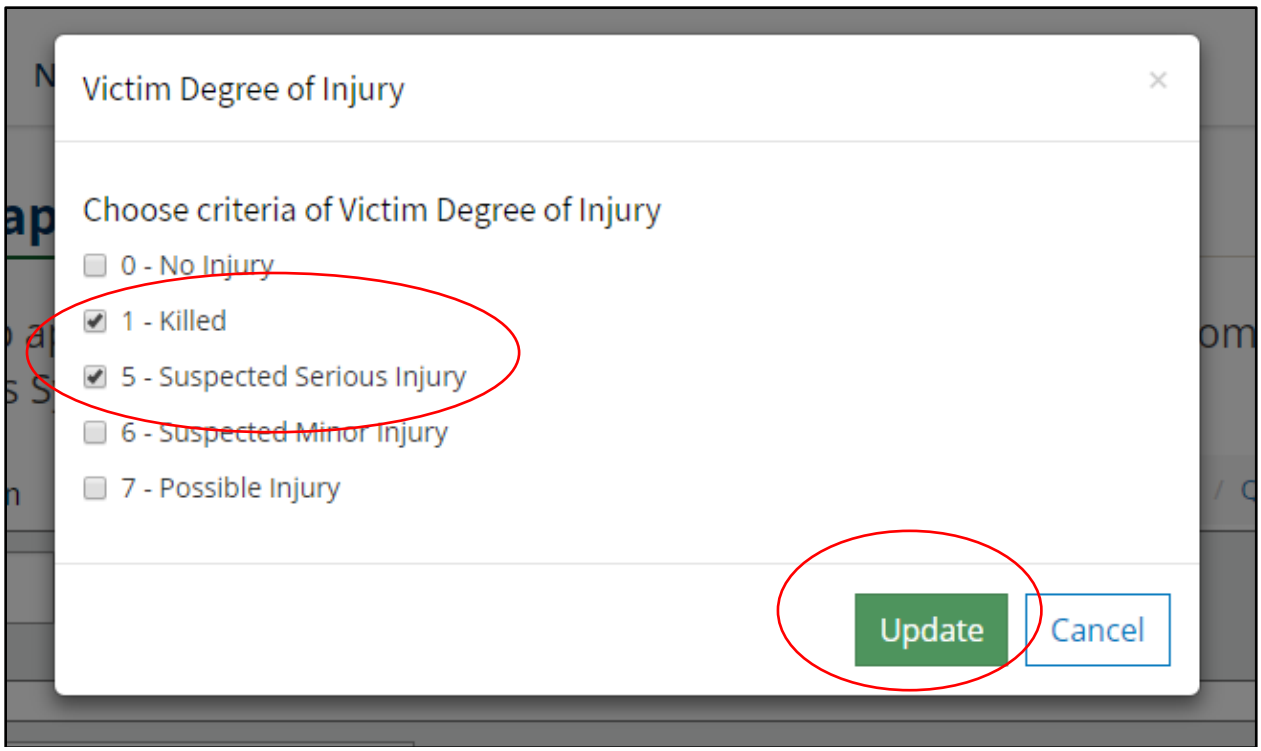
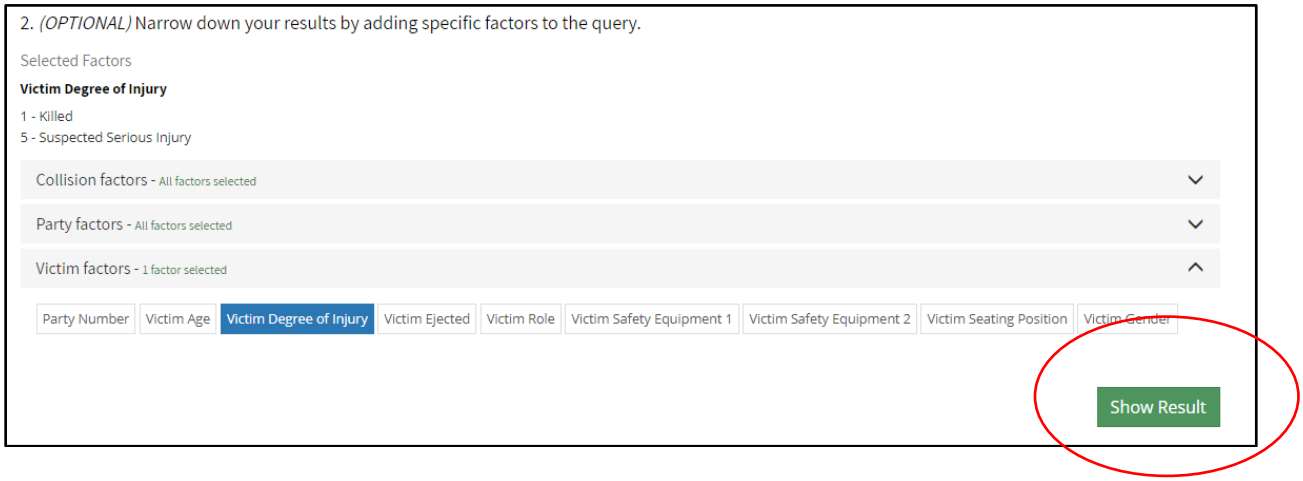
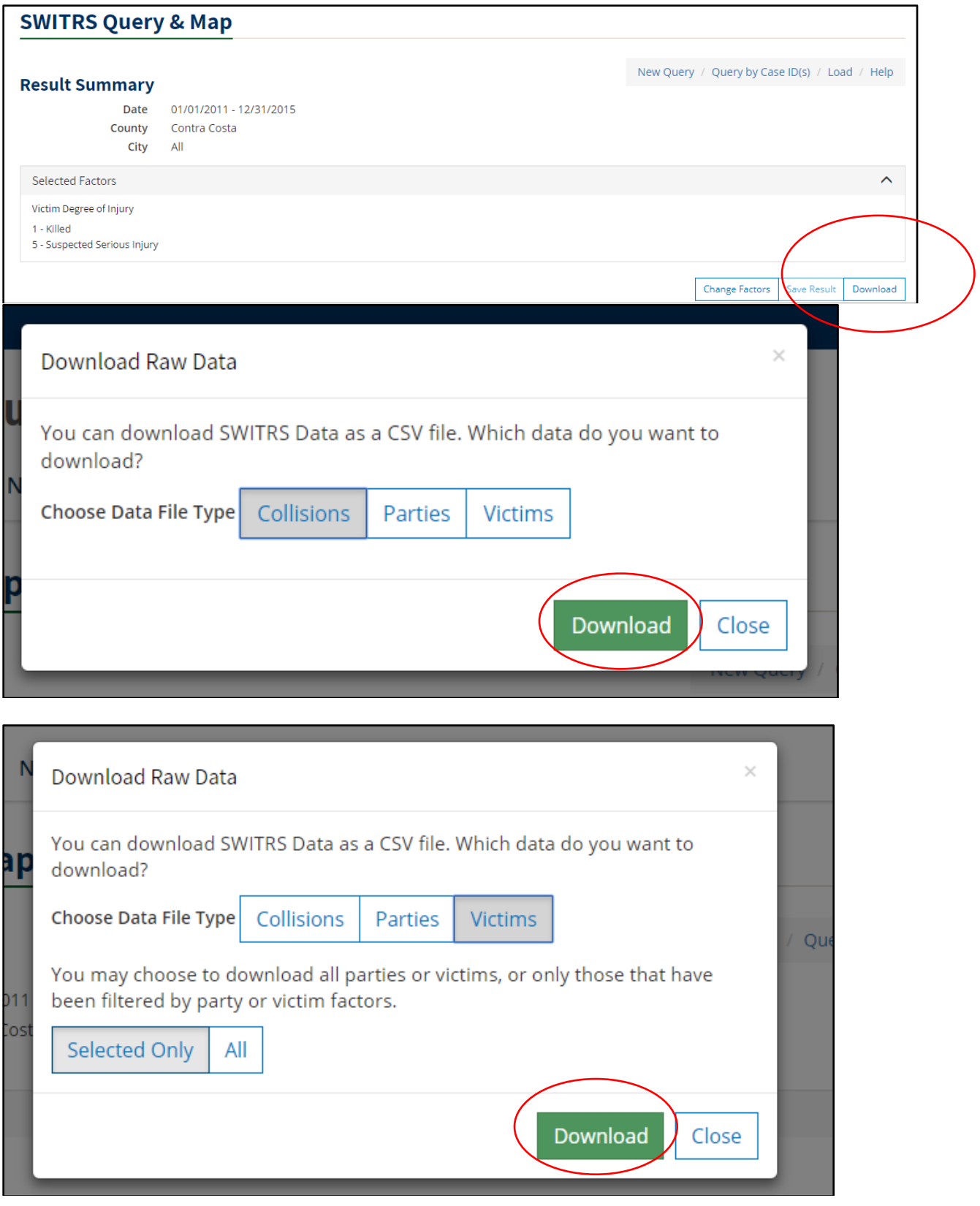


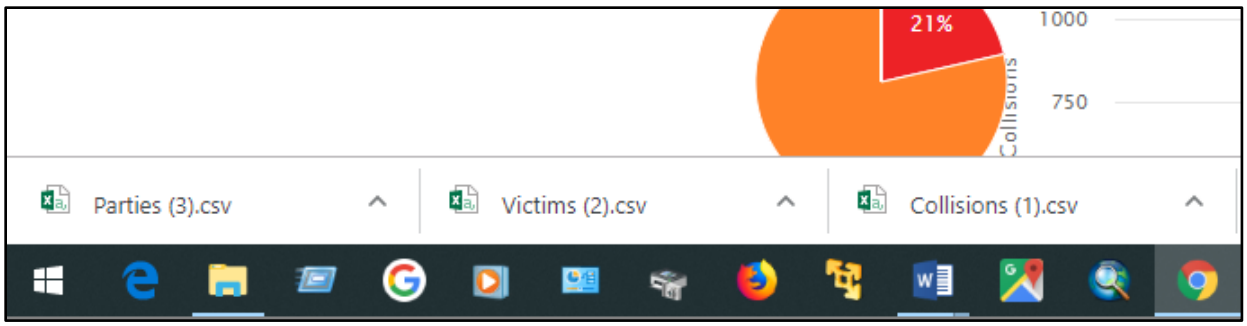
Figure 2. TIMS Interface for downloading SWITRS Data




Victim Degree of Injury
Choose criteria of Victim Degree of Injury
0 - No Injury
1 - Killed
5 - Suspected Serious Injury
6 - Suspected Minor Injury
7 - Possible Injury
Update
Cancel


2. (OPTIONAL) Narrow down your results by adding specific factors to the query.
Selected Factors
Victim Degree of Injury
1 - Killed
5 - Suspected Serious Injury
Collision factors - All factors selected
Party factors - All factors selected
Victim factors - 1 factor selected
Party Number
Victim Age
Victim Degree of Injury
Victim Ejected
Victim Role
Victim Safety Equipment 1
Victim Safety Equipment 2
Victim Seating Position
Victim Gender
Show Result


SWITRS Query & Map
New Query / Query by Case ID(s) / Load / Help
Result Summary
Date 01/01/2011 - 12/31/2015
County Contra Costa
City All
Selected Factors
Victim Degree of Injury
1 - Killed
5 - Suspected Serious Injury
Change Factors
Save Result
Download
Download Raw Data
You can download SWITRS Data as a CSV file. Which data do you want to download?
Choose Data File Type
Collisions
Parties
Victims
Download
Close
Download Raw Data
You can download SWITRS Data as a CSV file. Which data do you want to download?
Choose Data File Type
Collisions
Parties
Victims
You may choose to download all parties or victims, or only those that have been filtered by party or victim factors.
Selected Only
All
Download
Close



2. Spatially join collisions with roadway segments to assign roadway facility type (ArcGIS)

To perform this operation users must have a valid ARCGIS license and be familiar with spatial joins. The input files are created in an R program that appends each of the 30 county data files into a single file for collision, party, and injuries. The injury file is joined (on CASE_ID) with the collision file to assign x-y coordinates of the collision location to each injury victim. The coordinates are used in ArcGIS to create points, which are spatially joined to the nearest roadway segment. A shapefile of roadway segments for California Roads is provided by the U.S. Census TIGER program. Each roadway segment has a facility type attribute and standardized code (RTTYP, MTFCC) that describes whether it is a local road, arterial, highway, ramp, etc. A separate cross walk classifies the roughly 30 combinations of RTTYP and MTFCC codes to ITHIM's three facility types: local roads, arterials, and highway. The product of the ArcGIS spatial join is a file of injuries with the of RTTYP and MTFCC codes for facility type.

3. Assign each injury a victim mode of travel and a striking vehicle mode of travel (SAS)

A SAS program (Victim_Striking_Vehicle_Injury2006-2010matrix9-10-13.sas) originally developed to analyze 2006 to 2010 was modified to produce the 2011 to 2015 update. This file analyzes each collision, its, parties, and victims to assign a striking vehicle and a victim vehicle involved in the collision. This includes single party collisions (no other vehicles) as well as two and multiple party collisions. The SAS program incorporates a logic that for collisions with two or more parties, among the remaining vehicles, the vehicle with the largest mass is the striking vehicle using the precedence order: Truck > Bus > Car > Motorcycle > Bike > Ped.

Due to the size of the input file, a SAS system file is created (injury_matrix2015.sas7bdat) and is used to generate descriptive statistics of the typologies of injuries by severity and roadway by MPO region.

4. Construct an injury matrix in a standardized format (SAS)

After assignment of each injury to a cell of the injury matrix, another SAS program (item13_rti_matrix8-4-19.sas) imputes missing data and formats the output for spreadsheet versions of ITHIM. Missing data arises when collision locations are not geocoded or geocodeable, or the SWITRS data has incomplete information on the vehicle(s) involved in a collision, such as a

hit-and-run collision. Imputation is based on distributing missing injuries based on the cell frequencies predicted by marginal totals. The output of the SAS program is an Excel file (Item13rti_matrix2019-08-04.xlsx) that resembles the format of the 'Calibration Data' sheet of spreadsheet (Excel) ITHIM.

5. Input the matrix into the spreadsheet ITHIM (Excel)

There are 5 regional ITHIM workbooks for California. New versions of the spreadsheet ITHIM (version 8/6/2019) were copied from the previous version (12/12/2016). The rows in Item13rti_matrix2019-08-04.xlsx for specific MPOs were filtered and cut-and-pasted into the corresponding regional 'Calibration Data' worksheet (rows 374-625) of the new spreadsheet version. These cells populate those of 'Baseline injuries'. For the same scenarios, the 12/12/2016 and 8/6/2019 versions of spreadsheet ITHIM were visually compared for results in the worksheets 'Baseline injuries', 'Injury results', and 'Health Summary' for reasonableness based on a similar order of magnitude of results. (No unreasonable results were identified. Population attributable fractions for fatal and serious injuries appeared to be marginally higher for most regions for the updated 2011-2015 data.

6. Reformat the matrices for R/Shiny ITHIM (Excel)

After reasonableness checks, region-specific matrices in the 'Baseline injuries' worksheet were manually cut-and-pasted from Excel into a csv file (rti_baseline.csv). The California total was the sum of each corresponding regional cell.