Updating the Integrated Transport and Health Impact Model

Final Project Report

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Disclaimer

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ABSTRACT

California planners and policy makers face increasing demands for information on the health impacts of strategies to reduce greenhouse gas (GHG) emissions in transportation. The California Integrated Transport and Health Impact Model (ITHIM) is a tool that estimates the health impacts of replacing car travel with active modes (walking, biking, and transit). Active travel enhances physical activity, which reduces chronic disease, and reduces fine particulate matter and GHGs, which also threaten our health. ITHIM calculates the deaths, illness and costs that would be avoided if Californians increased their active travel. California ITHIM has been used since 2011 as an Excel workbook that was challenging to use. The purpose of this project was to develop California ITHIM as a user-friendly, open source, web application, while retaining the spreadsheet's functionality. The University of California, Davis convened an advisory group of representatives from 23 governmental and community-based organizations. We researched website designs and developed prototypes with reports, an infographic, tables, and graphs for a range of active travel scenarios. We then coded the designs using the R programming language and incorporated updated data. We linked the website to scientific publications, policies, best practices and other materials to help users identify strategies to improve health and safety in transportation.

Executive Summary

Background

California planners and policy makers are facing increasing demands for information on the health impacts of strategies to reduce GHG emissions in transportation, which is the single largest sector in California's GHG emissions inventory. Studies in California and elsewhere have identified the potential for health co-benefits of active travel in significantly reducing the existing burden of chronic disease. The California Integrated Transport and Health Impact Model (ITHIM) is a tool that estimates the health impacts of replacing car travel with active modes (walking, biking, and transit). ITHIM was conceived in 2010 by researchers in the United Kingdom to integrate the health impacts of physical activity from active travel, road traffic injuries, and fine particulate pollution in a single model. Using California data sources, a spreadsheet version of ITHIM was created by researchers in the California Department of Public Health in collaboration with the Metropolitan Transportation Commission (MTC) and the Bay Area Air Quality Management District. Since 2011, ITHIM has been successfully implemented by large and small metropolitan planning organizations (MPOs) in California, Nashville, TN, and by the states of Oregon, Maryland, and Vermont. ITHIM was implemented as an Excel spreadsheet that users found challenging to use and had limited reporting capability. Increasing the ease of using ITHIM provides users with a consistent methodology that can help organizations engage in better decision making on transportation and health.

Objectives and Methods

The University of California, Davis (UCD) proposed to create an easy-to-use open source version of ITHIM, capable of being maintained by CARB staff. The essential components of an updated web-based version are: 1) analytic engine in R, 2) mechanisms to upload/update pre-processed, aggregated calibration/baseline and scenario data, 3) a user-friendly interface to manage data and analysis options, 4) a dashboard for presenting travel and health results at varying levels of detail, and 5) documentation and links to training on the tool and calibration data and decision-support materials and to other ITHIM and CARB efforts.

Current and potential ITHIM users and small MPOs, state agencies, local health departments, and other stakeholders were invited by CARB and the UCD team to participate in an advisory group. We researched functionally similar websites, and, with the assistance of a graphics designer and design guidelines from CARB's Office of Communications, we developed wireframes and prototypes of web pages. These were presented to the advisory group for feedback through prototyping and four successive cycles of website development and revision.

We used the R programming language to convert the Excel formulae into an R-based analytic engine, which carried out the calculations of comparative risk analysis: 1) characterizing the population distribution of physical activity times from walking and cycling, changes in $PM_{2.5}$ concentrations as a function of car vehicle miles traveled (VMT), and injury risk as a function of vehicle miles traveled, 2) incorporating the exposure distributions into literature- and meta-analysis informed concentration-response functions, 3) calculation of the population attributable risk, and 4) calculation of the change in the burden of disease. We consolidated data from pre-existing ITHIM Excel spreadsheets and new data on air pollution into standardized data files.

We used the R Shiny package to create an HTML-based user interface that accepts user choices of built-in and user-defined travel scenarios, geographic population, and time period of interest. We created several output types: summary report, infographic, tables and graphs, which were available at three levels of detail. We also enhanced the website with decision support materials which provided strategies for increasing physical activity and safety from active travel and way to reduce air pollution, greenhouse gases, and VMT. These include scientific evidence for different strategies, policies, best practices, guidelines, case studies, data and other resources.

Results

The R/Shiny application has approximately 8000 lines of R/Shiny code and generates the California ITHIM website, which is accessible on a developmental server (https://cal-ithim.org/ithim). The software can be packaged as downloadable desktop application. The website has 16 pages, 57 photographs and icons, three video tutorials, and a template for 1 summary report, 1 infographic, 37 tables (including 22 detailed disease-specific tables), 35 graphs (including 22 detailed disease-specific graphs), 94 links to the scientific literature and other websites as resources. The outputs accommodate user choices of 8 scenarios, 36 geographic entities (California, 5 regions, 30 counties), and 9 time periods (2010 to 2050 in 5-year increments). Outputs can be saved as CSV files or PDFs. The website features robust content for decision-support. This includes links to 42 scientific reviews and articles that comprise the evidence for policies, possible changes to transportation systems and infrastructure to improve health outcomes.

Conclusions

The University of California, Davis successfully developed an open-source, web-based version of California ITHIM that is easy-to-use and provides users with a rich menu of scenarios and decision-support materials to explore the health impacts of active transport as a strategy for greenhouse gas reduction in California's transportation sector. Current and potential users at CARB, state, regional, and local government, and community-based organizations were engaged in the development of the software. With training, CARB staff will be able to maintain the website over the next 3 to 5 years, after which, updating of calibration data will be highly desirable.

INTRODUCTION

Background

California planners and policy makers are facing increasing demands for information on the health impacts of strategies to reduce GHG emissions in transportation, which is the single largest sector in California's GHG emissions inventory. Senate Bill (SB) 375 requires metropolitan planning organizations (MPOs) to reduce GHG emissions through land use changes and other strategies. Studies in California and elsewhere have identified the potential for health co-benefits of active travel in significantly reducing the existing burden of chronic disease. In California, an estimated 23,000 annual deaths statewide are due to physical inactivity.

Several MPOs have set voluntary health targets in their Sustainable Communities Strategies and have used a spreadsheet version of California Integrated Transport and Health Impact Model (ITHIM) to estimate the health impacts of their preferred scenarios. The historical platform for ITHIM has been an ensemble of 5 regional Excel workbooks, each with 35 individual worksheets containing thousands of cells of aggregate data and formulae. While the spreadsheet versions are standardized, highly functional, and well-documented, they are not user friendly, nor do they have statewide coverage for assessing air pollution-related health impacts, or a means to easily pool results for a statewide analysis. Increasing the ease of using ITHIM provides users with a consistent methodology that can help organizations engage in better decision making on transportation and health.

ITHIM was conceived in 2010 by researchers in the United Kingdom to integrate the health impacts of physical activity from active travel, road traffic injuries, and fine particulate pollution in a single model. Under the direction of Dr. Neil Maizlish (then at the California Department of Public Health) and using California data sources, a spreadsheet version of ITHIM was created in collaboration with the Metropolitan Transportation Commission (MTC) and the Bay Area Air Quality Management District. Since 2011, ITHIM has been successfully implemented by large and small California MPOs (MTC, Fresno Council of Governments, Sacramento Area Council of Governments, and San Diego Association of Governments), Nashville, TN, and the states of Oregon, Maryland, and Vermont.

Goals/Objectives of Project

The project goals were:

- To translate existing functionality of spreadsheet ITHIM to an open source, web-based platform that is:
    - Easy to access and use by state agency scientists; policy analysts and planners in state, regional, and local government; academics; and community-based organizations, and

- Easy to maintain by staff of the California Air Resources Board (CARB).

Scope of this Report

This report describes the work conducted by the University of California, Davis in the fulfillment of its contract to develop a software application to replace a hard-to-use spreadsheet version of the ITHIM model with one that is user-friendly, open-source, and web-based. The scope of work was not to develop a new model or alter the conceptual basis of the existing ITHIM model. The ITHIM model and its implementations in California have been extensively published in peer-reviewed journals and we briefly summarize the comparative risk assessment methodology below.[1-8] Readers unfamiliar with comparative risk assessment methodology should consult these publications. Explanatory materials about the model and tutorials to help users understand the model inputs and outputs were part of the scope of work, and are covered in the Results section of this report.

Conceptual Basis of ITHIM

Previous research has identified physical activity, air pollution, and traffic injuries as the main, direct pathways of transportation-related health co-benefits and harms.[9] The Integrated Transport and Health Impact Model (ITHIM) estimates the change in the population disease burden due to a shift from a baseline travel pattern to an alternative with greater active transport. The approach and application to transport and health have been described previously.[3, 5-7, 10]

The model incorporates an extension of the population attributable fraction, which is used in public health to describe the percent of disease or injury that could be avoided in a population by eliminating a risk factor such as lack of physical activity. The population burden of disease was measured in disability adjusted life years, DALYs, which are the sum of years of life lost due to premature mortality and years of living with disability. The population attributable fraction was estimated from exposure-response relationships between a) the risk factor and the health outcome for specific causes, and b) the exposure distribution of the risk factor in the baseline population and in the alternative. ITHIM incorporates specific chronic diseases that have strong evidence from systematic reviews of a relative risk (RR)-exposure gradient for physical activity. These include cardiovascular diseases (ischemic heart disease, hypertensive heart disease, and cerebrovascular disease), colon cancer, breast cancer, diabetes, depression, and dementia, which account for 37% of the burden of disease and injury in the United States.[11]

Physical activity encompasses both travel and non-travel related physical activity, including leisure and occupational activities. Daily or weekly activity times were multiplied by weights to give metabolic equivalent task (MET) hours,[12] which reflect energy expenditures for walking and bicycling at average speeds and for occupational tasks.

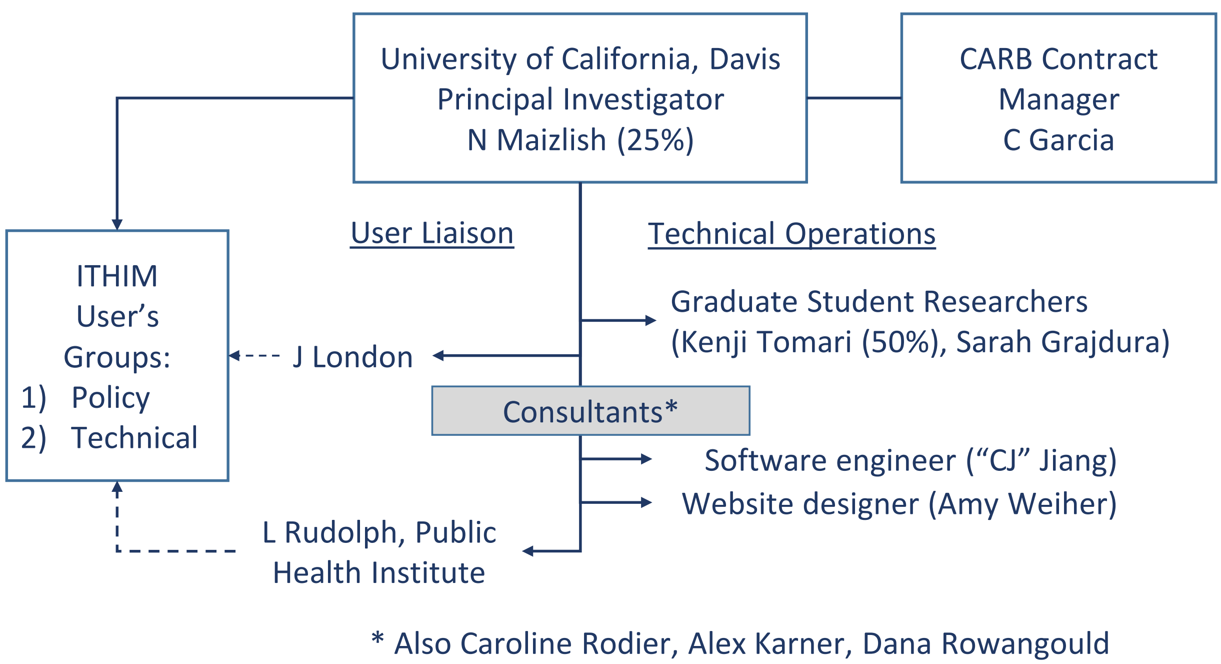
For traffic injuries, a distance-based model was used. Injuries were estimated by multiplying change in miles traveled of one or more parties to a collision for each pairwise combination of victim and striking vehicle (pedestrian, bicyclist, motorcycle, car, bus, truck) by the baseline rate per mile traveled for injuries of that combination of modes. A square root function was applied to travel miles to account for the observation that pedestrian and bicyclist injuries tend to be lower at higher mode shares – "safety-in-numbers".[13] Injury risks were stratified by severity (fatal, serious) and roadway type (local, arterial, and highway), which indirectly takes into account the role of speed and traffic volume in traffic injuries.

To estimate exposure to air pollution, we used population-weighted means of air-borne fine particulate matter ($PM_{2.5}$), based incidence per ton of $PM_{2.5}$ and NO_x emissions. The RR-$PM_{2.5}$ gradient in the comparative risk assessment (CRA) analysis reflected the change in risk over an increment of $10\mu g/m^3$ $PM_{2.5}$.[14]

Project Organization and Planning

The project was formalized as a service contract (17RD025) between CARB and the Department of Human Ecology, University of California, Davis, with Drs. Neil Maizlish and Jonathan London co-Principal Investigators. Two part-time graduate students researchers (GSR) and 3 paid consultants (software engineering, web design, community engagement) made up the project team (Figure 1).

Figure 1. ITHIM Update Project (17RD025) Organizational Chart



Funding for Ms. Grajdura's part-time position was available only for the summer 2018 academic quarter. However, supplemental funding (15% effort, 8 months) was obtained from the Nicholas Linesch Legacy Fund (https://nicolineschlegacy.jewishfoundationla.org/), administered by the Public Health Institute, Oakland. Under the direction of Dr. Maizlish, Ms. Grajdura focused on "wish list" tasks identified the appendix to the project proposal (i.e. out-of-project scope but highly desirable).

Between June 28, 2018 and September 23, 2019, we conducted 56 one-hour, weekly project team meetings (Maizlish, Tomari, Weiher, Jiang) for project planning, administration, and assessing progress. On several occasions we invited a technical expert (Kelley Rodgers, Executive Director, ThinkStreetSmart.org) to participate in staff meetings. A separate weekly meeting, initiated in September 2018 with Maizlish, Tomari, and Jiang, focused on identifying and resolving technical issues related to establishing a developmental website to test the ITHIM application, identifying modules for the analytic engine, coding strategies, and documentation.

MATERIALS AND METHODS

The next section describes how we integrated stakeholder engagement, prototyping of web designs, organization of data, air pollution data, and the development of the application interface and analytic engine.

Stakeholder Engagement

We constituted a multi-sectoral User's Group (Table 1) of California stakeholders. Potential candidates were recruited from: 1) CARB Research Division staff with support from the Office of Communications and the Office of Information Services, 2) Drs. London and Rudolph's professional network of health, equity, environmental justice, and climate organizations, 3) metropolitan planning organizations who had previously worked with Dr. Maizlish to implement ITHIM in their organization, and 4) educational and advocacy organizations with prior experience using published results of ITHIM. The initial list included CARB staff, state agency stakeholders, MPOs, local health departments and local government representatives and community-based organizations.

Forty-three representatives of 27 organizations participated in one or more of the 4 quarterly 90-minute conference calls from July 27, 2018 to March 27, 2019. The users group was a mix of a) local, regional, and state government, b) transportation and health agencies, and c) non-profit community-based organizations. The group included transportation modelers, transportation planners, public health managers and epidemiologists, policy experts, and sustainability managers.

Table 1. California ITHIM Update Project User's Group, July 2018 - May 2019

Organization	Geography/Type	Sector	Persons	Orientation
Bay Area Air Quality Management District	Regional/govt.	Air quality	2	Technical
Bay Area Regional Health Inequities Initiative	Regional/govt.	Public health	1	Policy
California Air Resources Board	State/government	Air quality	3	Technical
California Council of Governments	State/government	Trans./Land use	1	Policy
California Environmental Justice Alliance	State/advocacy	Environmental justice	1	Policy
California Walks	State/advocacy	Active travel	1	Policy
California Department of Transportation (Caltrans)	State/government	Transportation	3	Policy
California Department of Public Health	State/government	Public health	3	Technical
California Lung Association	State/advocacy	Public health	2	Technical
Climate Plan California	State/advocacy	Climate change	2	Policy
Fresno Council of Governments	County/government	Transportation	1	Technical
Institute for Local Government	State/advocacy	Planning	1	Policy
Los Angeles County Department of Public Health	County/government	Public health	3	Technical
Local Government Commission	State/advocacy	Govt. administration	1	Policy
Metropolitan Transportation Commission	Regional/govt.	Transportation	2	Technical
Public Health Alliance of Southern California	Regional/advocacy	Public health	2	Policy
Sacramento County Office of Sustainability	County/government	Environmental	1	Technical
Sacramento County Health Department	County/government	Public health	2	Technical
Sacramento Area Council of Governments	Regional/govt.	Transportation	1	Technical
Safe Routes to School Partnership	State/advocacy	Active travel	1	Policy
San Diego Association of Governments	Regional/govt.	Transportation	1	Technical
Southern California Association of Governments	Regional/govt.	Transportation	1	Technical
San Francisco Department of Public Health	County/government	Public health	2	Technical
Strategic Growth Council	State/government	Planning	1	Policy
San Joaquin Valley Latino Environ. Advancement	Regional/advocacy	Advocacy	1	Policy
Sacramento Metropolitan Air Quality Mgt. District	Regional/govt.	Air quality	2	Technical
Walk Sacramento	State/advocacy	Active travel	1	Policy
Total	27		43	

Invitees unable to attend included Office of Planning and Research, Transform, Public Advocates, and California Bicycle Coalition

The purpose of the User's Group was to provide input and feedback of the design of the web-based ITHIM application. User Group meetings were conducted virtually using commercial meeting software with screen sharing and telephone and computer audio. CARB staff provided feedback on drafts of meeting agendas and presentation slides; final versions were sent to User's Group members by email prior to meetings. Due to the challenge of accommodating a large group, for several User Group meetings, we repeated the conference call on two dates to maximize participation if no single date/time met most users' schedules. Meetings were recorded and written summaries (with links to the recordings) were distributed to participants after each conference call. Table 2 summarizes the topics and meeting schedule, and Appendix A comprises the meeting summaries.

Table 2. User Group Conference Calls and their Agendas

Call	Date(s)	Topics
1	July 25, 2018	Technical Users: Goals of ITHIM Update Project, Current State of California ITHIM, Policy Users' Needs, Initial Ideas of Website Design
1	July 30, 2018	Policy Users: Goals of ITHIM Update Project, Current State of California ITHIM, Policy Users' Needs, Initial Ideas of Website Design
2	October 24 and 29, 2018	Organization of Draft Website, Style Guidance from ARB, Home Page (draft), Tool Page (draft), inputs (Interface), Outputs (Chart book)
3	February 5, 2019	Review of the "Alpha" Web ITHIM: Home Page, About Pages, Tool Page, Decision Support Pages, User Support Page
4	March 25, and 27, 2019	Review of "Beta" Web ITHIM: Home Page, About Pages, Tool Page, Decision Support Pages, User Support Page

The first User's Group meeting was conducted in two sessions, one for technical users and one for policy oriented users. This was done to ensure that the focus of the meetings matched the vocabulary, skills sets, and needs of the different kinds of users. The successive meetings (technical and policy combined) previewed draft web page designs, which incorporate responses to feedback from the prior meeting, and initial designs of new pages for which feedback was sought.

<u>Small MPOs</u>

We also conducted a 90 minute conference call on November 15, 2018 with three representatives of smaller MPOs to assess their interest and capacity to use a web-based ITHIM R/Shiny tool. Based on the experience of FresnoCOG, which implemented the spreadsheet version in 2016-2017, participants observed that smaller MPOs in the Central Valley autonomously run travel demand models, whose outputs can be formatted as inputs to ITHIM. Although beyond the scope of this project, there was interest in pooling and augmenting resources (via grant opportunities) to do this.

Software Application Development

This contract required the development of a software application written in the R programming language[15] and one of its packages called Shiny.[16] R is an open-source, free statistical computing program, which was used to perform the calculations in the comparative risk assessment methodology implemented in California ITHIM. (A detailed description of the comparative risk assessment methods is provided in "Chapter 1. Concept", *California ITHIM User's Guide & Technical Manual*.[17]) Shiny generates HTML5 code that can be read by web browsers (e.g. Chrome, Edge, Firefox, Internet Explorer, Opera, Safari) to format text, tables, graphs, photographs, and images as web pages. Shiny also incorporates modern web styling of text and web page elements using cascading style sheets (CSS). Readers unfamiliar with the basic mechanics of programming web pages should refer to introductory materials.[18]

The software application has two conceptual parts: 1) an interface and 2) an analytic engine. The interface includes web pages whose content is read, but does not change and interactive web pages in which the user can run the ITHIM model with inputs selected from picklists. Along with calibration data, these interactive inputs are passed to the "back-end" of the application where mathematic calculations are carried out, and whose results are returned to the interface for visualization as reports, infographics, tables and graphs.

Interface

The development of the user interface or web pages started with a literature review and progressed through design phases that included prototyping, guidance from the CARB Office of Communications, feedback from the User's Group, and coding in R/Shiny.

Literature Review

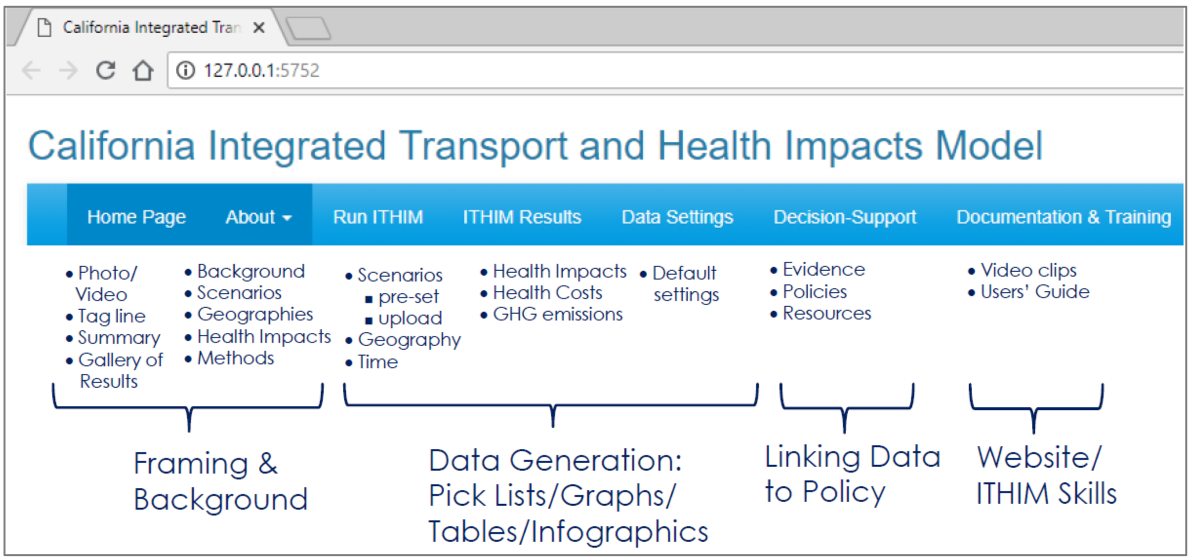
We reviewed different types of websites that provided potential design information. These included 1) commercial websites with large number of page views (e.g., Amazon, Nike), 2) websites of other ITHIM developers,[19-24] and 3) websites with web content related to transportation, health, and climate change.[25, 26] We also consulted the data visualization chapter in *R for Data Science*[27] on using the ggplot2 (grammar of graphs) package for the styling of bar and line charts in R. The synthesis of the literature review indicated that modern web sites conform to a standard design that users have internalized. These include a Home Page, About Pages, User Interactive Page (if applicable), and additional pages for decision support and user support (i.e. tutorials). To increase user acceptance and minimize the learning curve for website navigation, we decided to design the California ITHIM website using a standard design.

Wireframes and Schematic Diagrams

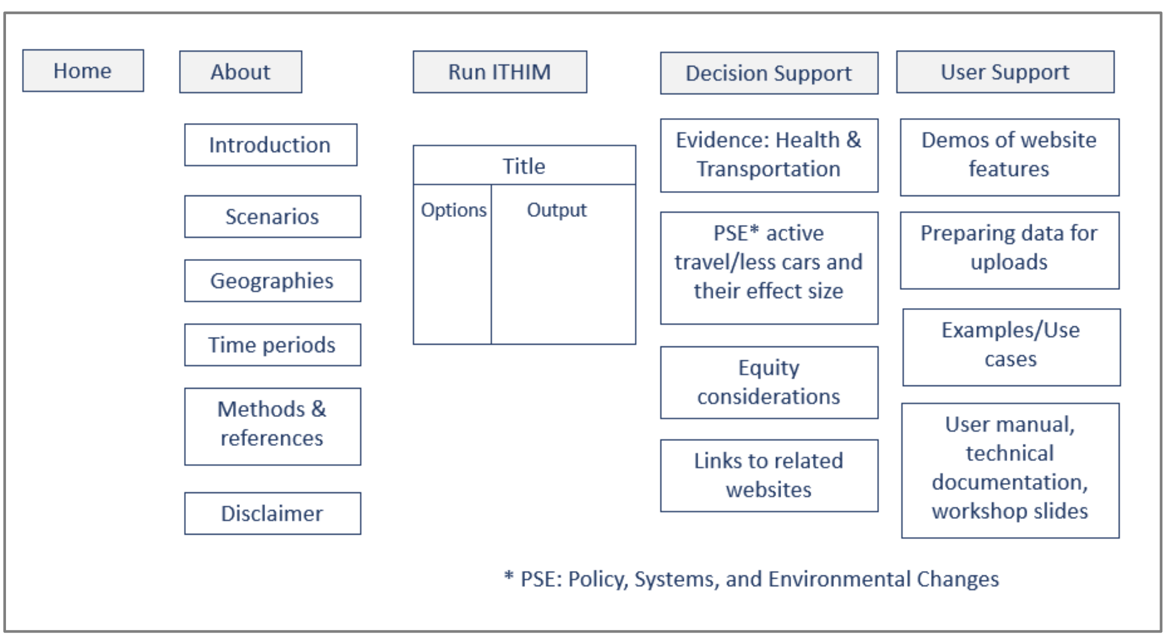
We created a rough draft of content areas for each of the major pages. In the first User's Group meeting, we presented these conceptual "standard" web pages as "wire frames" and as a schematic of website content (Figure 2, A-B).

Figure 2. Development of the California ITHIM Interface

A. Schematic of Website Content (August 6, 2018)



B. Wire Frames (August 6, 2018)



Prototyping of Web Pages as PDFs and CARB Guidance

Our web designer used several inputs in drafting prototypes of web pages. First, she used the wire frames and schematics. Second, in the early phase of the project, we consulted with the CARB Office of Communications to learn about the recommended style guidelines for CARB's own website (https://ww2.arb.ca.gov/homepage). The CARB style guidelines cover style elements such as page divisions, text font and size, color palette for text and background elements, selection of photographs and images, and use of the CARB logo.[28, 29]

We followed CARB's Office of Communications recommendation that the ITHIM Update Project flexibly adhere to CARB's style guidelines, but not necessarily reproduce CARB web pages in exact detail.

With this guidance in mind, our web designer created a mock-up of web pages using In-Design graphic design software, which generated a PDF facsimile of a webpage. An example of the evolution of the Home page is presented in Figure 3, A-B.

Feedback from CARB and the User's Group

The PDFs of web pages were presented to CARB staff (Research Division and Office of Communications) for their feedback, and revised PDFs were presented to members of the User's Group at meetings for their feedback. (The details of this feedback are provided in Appendix A. User Group Meeting Summaries.)

Prototyping Key Tables and Graphs for the Tool Page

We developed a series of key tables and bar and line graphs that illustrated the content to be generated by the analytic engine. These were compiled as a chart book (Appendix B), which was presented at the second user group meetings (October 2018) and reviewed by ARB staff and users for depth and breadth. The charts were organized by level of detail that would appeal to policy (summary) and technically-oriented (detailed) users.

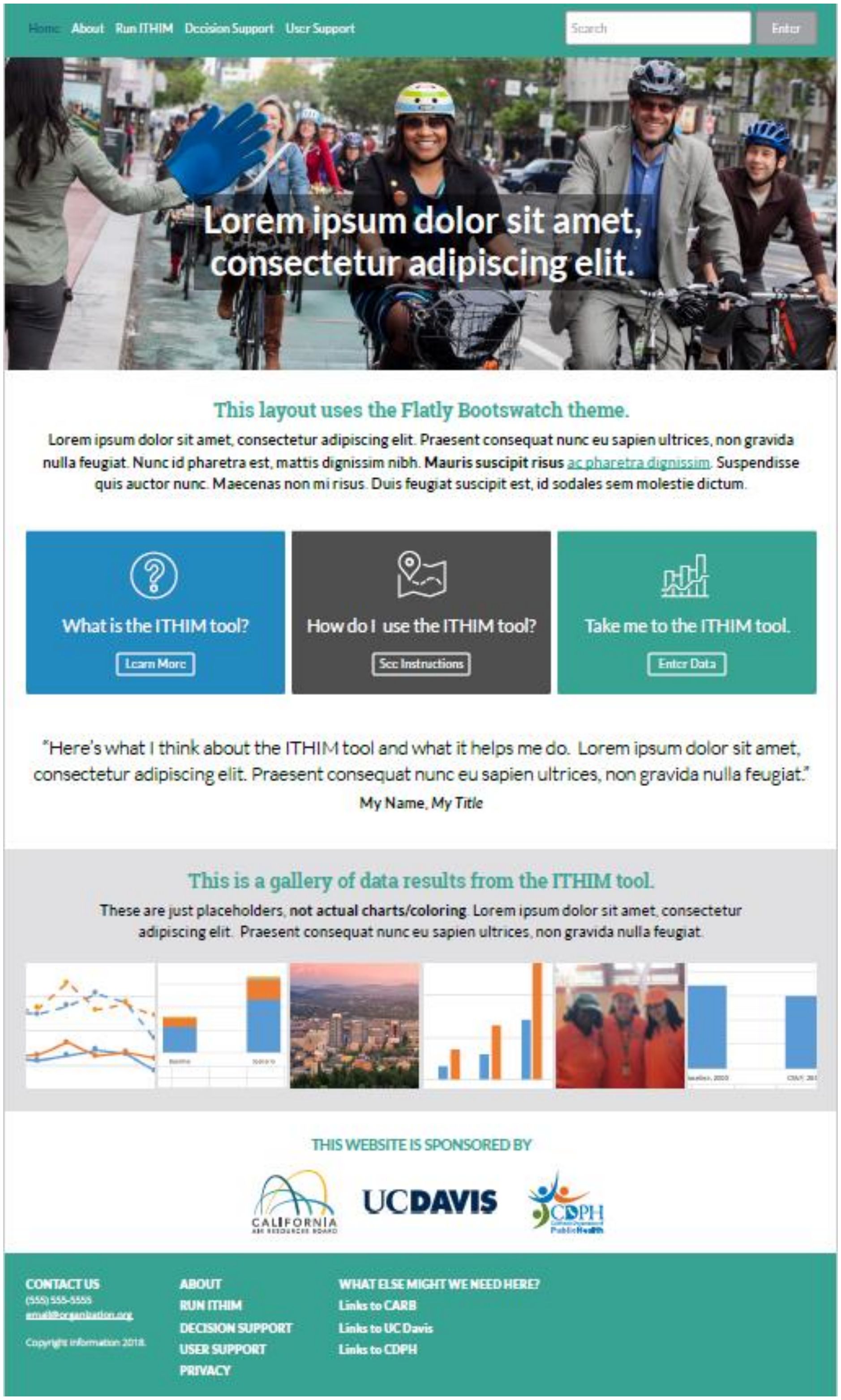
Coding of Web Pages in R/Shiny

To translate the PDF mock-up into an actual webpage, we used free software called RStudio, which was developed by a company of the same name. RStudio (the software) provides an integrated development environment (IDE) for R programmers using desktop computers (Windows and Apple operating systems). RStudio IDE has a console, source code editor that supports direct code execution, as well as tools for plotting, history, debugging and workspace management. It has an interface to visualize the products of executed code (i.e. web pages) in the programmer's web browser. Shiny is a software package that runs in conjunction with the R program and RStudio IDE.

Figure 3. Development of the California ITHIM Interface (Wireframes)
A. Wire Frames, Home Page (August 14, 2018)

Figure 3. Development of the California ITHIM Interface (continued)

B. PDF of Home Page (Version 1, August 28, 2018)



Dr. Maizlish and Kenji Tomari wrote R programs on their desktop computers that translated each element of the PDF into its corresponding HTML tag and style (CSS) elements. These elements included title tab with a favicon; page title; navigation bar; side-bar menus; page footer; page tabs; fonts sizes and colors for primary, secondary, tertiary and quaternary headings (h1, h2, h3, h4) and paragraph text; horizontal and vertical page divisions (i.e., rectangular "containers") for content and their background colors; images (photographs, icons) and video files. Shiny has 1) specific commands whose format and syntax mimic HTML and CSS commands and 2) a generic command that directly accepts HTML and CSS commands into the R Code (Figure 4). The coding of interface components was done in the "ui" section of the Shiny application. The coding process was facilitated by tutorials provided by RStudio and an internet-based community of R programmers who post programming questions, answers, and code snippets on a free electronic bulletin board called Stackoverflow (https://stackoverflow.com/). Styling elements based on CARB's style guidelines are presented in Table 3. To manage the text in web pages we created a CSV-formatted text file (called webtext.csv), which contained titles, text, hyperlinked text, and bulleted lists (Figure 5).

We also created a similar CSV-formatted file called "webphotoimage.csv" that provides a unique identifier for each element and file names of photographs and images. The file also contained text ("alt") that is incorporated into HTML of images on web pages. Special software reads web pages and makes a description of the photograph or image accessible to those with visual impairments. Each of these elements were indexed with a unique identifier that linked to the R/Shiny code, which positioned the element on the web page using HTML and CSS (Figure 5).

Photographs and Images

Modern and appealing websites incorporate photographs, icons, and other images to communicate and enhance the user experience. We incorporated banner photographs on each web page and used icons on the Scenarios page, RunITHIM page, and User Support pages. We relied on high resolution, commercial (iStock) photographs from CARB's photo library with permission from the Office of Communications. These were supplemented by stock photographs purchased by the project, and, in a few instances, free photographs with a Creative Commons license. Banner photographs were cropped to 2000 by 400 pixel dimensions using Adobe Photoshop software. Icons were developed by the graphic artist. Icons and smaller images were edited from screen shots of pdfs to 200 by 200 pixel dimensions in the MS Windows bitmap editor (Paint).

The favicon (favicon.ico) was created with the string "ITHIM California" using open source, free software called ImageMagick version 7.0.8 (https://imagemagick.org/).

The file "webphotoimage.csv" has a complete listing of photographs and images used in the R/Shiny application.

Figure 4. Example of R/Shiny Commands and Associated HTML

R/Shiny Commands

```
ui <- fluidPage (list(tags$head(HTML('<link rel =
"icon", href = "favicon.ico",
   type="image/png" />'))),
    theme = "bootstrap2019-02-25.css",

titlePanel(windowTitle = "ITHIM California",
  div(class ="ithimtitle",
  div(class = "versiontext",
    p(webtext[webtext$Element == "hp.versiontext",
   "Content"])),
    tags$img(src  = webfoto[webfoto$Element ==
   "hp.wordmark","Filename"],
    alt  = webfoto[webfoto$Element ==
    "hp.wordmark","Alttext"],
    title = webfoto[webfoto$Element ==
   "hp.wordmark","Title"])
  ) # End division class ITHIM title
), # End Title Panel

# Navigation bar
navbarPage("", id = 'tabs', position =
   c("static-top"),

tabPanel(h4("Home"), value = "#Home",
  fluidRow(div(class = "phototext" ,
  style = "background-image:
  url('home_page_banner2000by750.png');",

  tags$img(src = webfoto[webfoto$Element ==
  "hp.banner","Filename"]),
   alt   = webfoto[webfoto$Element ==
   "hp.banner","Alttext"],
  title = webfoto[webfoto$Element ==
  "hp.banner","Title"],
  style = "height:80vh;"),

            . . . more lines of code . . .
```

HTML

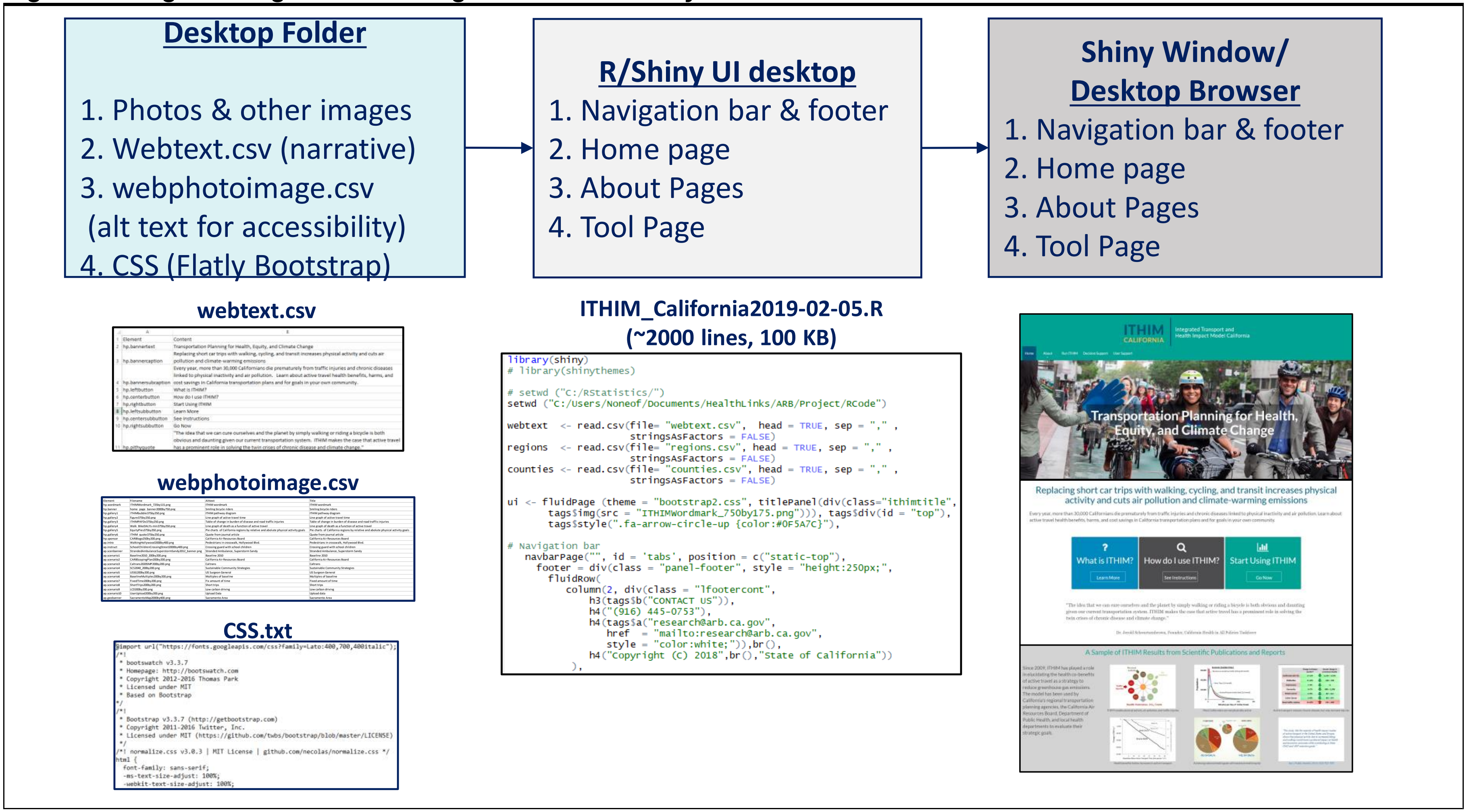
```
<div class="container-fluid">
  <h2>
    <div class="ithimtitle">
      <div class="versiontext">
        <p>DRAFT FOR DISCUSSION ONLY - Website
Under Construction - UC Davis - April 24, 2019</p>
      </div>
      <img src="ITHIMWordmark_725by115.png"
alt="ITHIM wordmark" title="ITHIM wordmark"/>
    </div>
  </h2>
  <div id="top"></div>
  <style>.fa-arrow-circle-up
{color:#0F5A7C}</style>
  <nav class="navbar navbar-default navbar-static-
top" role="navigation">
    <div class="container-fluid">
      <div class="navbar-header">
        <span class="navbar-brand"></span>
      </div>
      <ul class="nav navbar-nav shiny-tab-input"
id="tabs" data-tabsetid="7790">
        <li class="active">
          <a href="#tab-7790-1" data-toggle="tab"
data-value="#Home">
            <h4>Home</h4>
          </a>
        </li>
        <li class="dropdown">
          <a href="#" class="dropdown-toggle" data-
toggle="dropdown" data-value="&lt;h4
style=&quot;width:5em;text-
align:center&quot;&gt;About&lt;/h4&gt;">
            <h4 style="width:5em;text-
align:center">About</h4>

            . . . more lines of code . . .
```

Table 3. Style Guidelines for Font Type, Size, Height, and Color, California ITHIM Website

Element	HTML Tag	Division class	CSS Styling	Style size	Color (hex, rgb)
1. Font Type			Lato		
2 Text					
Homepage Banner caption	h1	bannercaption	font-size:6.0vh	~80px	white
Homepage Banner subcaption	p	Banner-subcaption	font-size:125%	28px	dark gray #4D4D4F, (77,77,79)
Other Page Titles	h1	aptitle	font-size:400%	32px	dark blue #0F5A7C, (15,90, 124)
Subheaders (kickers)	h2	apkicker	font-size:100%	24px	turquoise #36A393 (54,163,147)
Sub-, subheaders (subkickers)	h3			18px	medium blue #1F8BBF (31,139.191)
Paragraphs	p	apkickertext	font-size:125%; line-height:125%	16px	dark gray #4D4D4F, (77,77,79)
Footer text	h4	lafooter	Line-height:150%	13px	white
3. Banner photographs	img			2000 by 400 px	
4. Tables					
Header row background	th				turquoise #36A393 (54,163,147)
Header text	th				white
Row background (zebra)	tr				light blue #deeaf6, (222, 234, 246)

Figure 5. Programming Text and Images into the R/Shiny ITHIM Interface



Analytic Engine

Prior R-ITHIM Projects

In two previous projects [22, 23] Dr. Maizlish assisted investigators with developing R programs to convert California versions of spreadsheet ITHIM to a more automated platform. The first R ITHIM version in the Unites States was developed by researchers at the University of Wisconsin. This version included physical activity and road traffic injuries, but not air pollution in health impact assessment. Calibration data on physical activity and road traffic injuries was based on national data sources. Scenarios were comparisons of regional differences in travel patterns in the United States. The application incorporated many R packages beyond basic R and used an advanced paradigm of programming called object-oriented programming.[30] No web-based user interface was developed for this project. Documentation geared to publishing R packages was available, but this documentation did not provide detailed data dictionaries for input files, or flow charts of functions. The program code was not accessible to our staff without a considerable investment in time and effort. We discussed this with the University of Wisconsin researchers (S. Younkin and J Patz, 6/23/2018), who acknowledged our concerns. This was essentially the first attempt to convert spreadsheet ITHIM to the R platform, and researchers convincingly demonstrated a proof-of-concept using advanced R programming methods.

The version by Alex Karner (now at University of Texas, Austin) included the health impact pathways of physical activity and road traffic injuries, but not air pollution. The application calculated health impacts for several Sacramento area counties and the Sacramento region. It included one scenario with race/ethnicity subgroups, and used advanced R packages. Calibration data was exported from the Sacramento Area spreadsheet version of ITHIM, and reformatted as an R program input. A rudimentary user interface in Shiny was developed. The application was open source, web-based and hosted for free by RStudio. The hosting service by RStudio did not provide stringent cybersecurity measures. The Sacramento version was an important advance in its modification of mortality data files as the basis for race/ethnicity equity analyses.

Programming Philosophy

While each attempt at creating a web-based R/Shiny ITHIM made important advances, none provided a complete model for the current project. None were statewide in geographic scope, nor did they include the air pollution health pathway or a robust user interface. The use of object-oriented programming and advanced R packages also raised questions in the UCD development team whether CARB staff (or future contractors) would have the skill sets necessary for code maintenance after the completion of this project. (R is not currently an enterprise computing package at CARB, but is available to individual CARB researchers.) The use of multiple advanced R packages also raised concerns of potential application failures due to incompatibilities in software updates.

We discussed our concerns with representatives from the CARB Research Division and the Office of Information Services. To reduce risks of software failure and increase the likelihood that CARB staff could maintain the R/Shiny code, CARB staff and UC Davis agreed to develop the R/Shiny ITHIM application 1) using simpler and more traditional programming paradigms such as structural/procedural programming, and 2) limiting additional R packages to those that were necessary to meet essential requirements (Table 4).

Table 4. Software Used to Develop the California ITHIM Software Application

Software/ Package	Purpose	URL
RStudio	Provides an integrated development environment for R developers (software development process, debugging)	https://www.rstudio.com/products/rstudio/download/
R	Use for statistical computing and graphics (analytic engine)	https://www.r-project.org/
shiny	Creates web (HTML) envelop for R programs (interface)	https://shiny.rstudio.com/
ggplot2	Creates publication grade graph (interface)	https://ggplot2.tidyverse.org/
grid	Enhances formatting of graphs (interface)	https://www.rdocumentation.org/packages/grid/versions/3.6.0
png	Reads, writes and displays bitmap images stored as a PNG (portable network graphics) format infographic)	https://cran.r-project.org/web/packages/png/png.pdf
digest	Checks whether data stored on a server has been corrupted (data integrity)	https://cran.r-project.org/web/packages/digest/digest.pdf

I/O Diagrams and Core Equations

We approached the programming of the analytic engine by creating input-output diagrams (Figure 6) and mathematically defining the core analytic procedures to carry out comparative risk assessment for diseases related to physical activity (Table 5), physical activity and $PM_{2.5}$ (Table 6), $PM_{2.5}$ alone (Table 7), and road traffic injuries (Table 8). The core procedures were coded as R functions that accept user-selected arguments of scenario, geography, and time period (Figure 7). The core procedures are:

- Quantify exposures for physical activity, $PM_{2.5}$, and road traffic injuries based on travel time and distance
- Quantify exposure-health risk distributions for the baseline and scenario

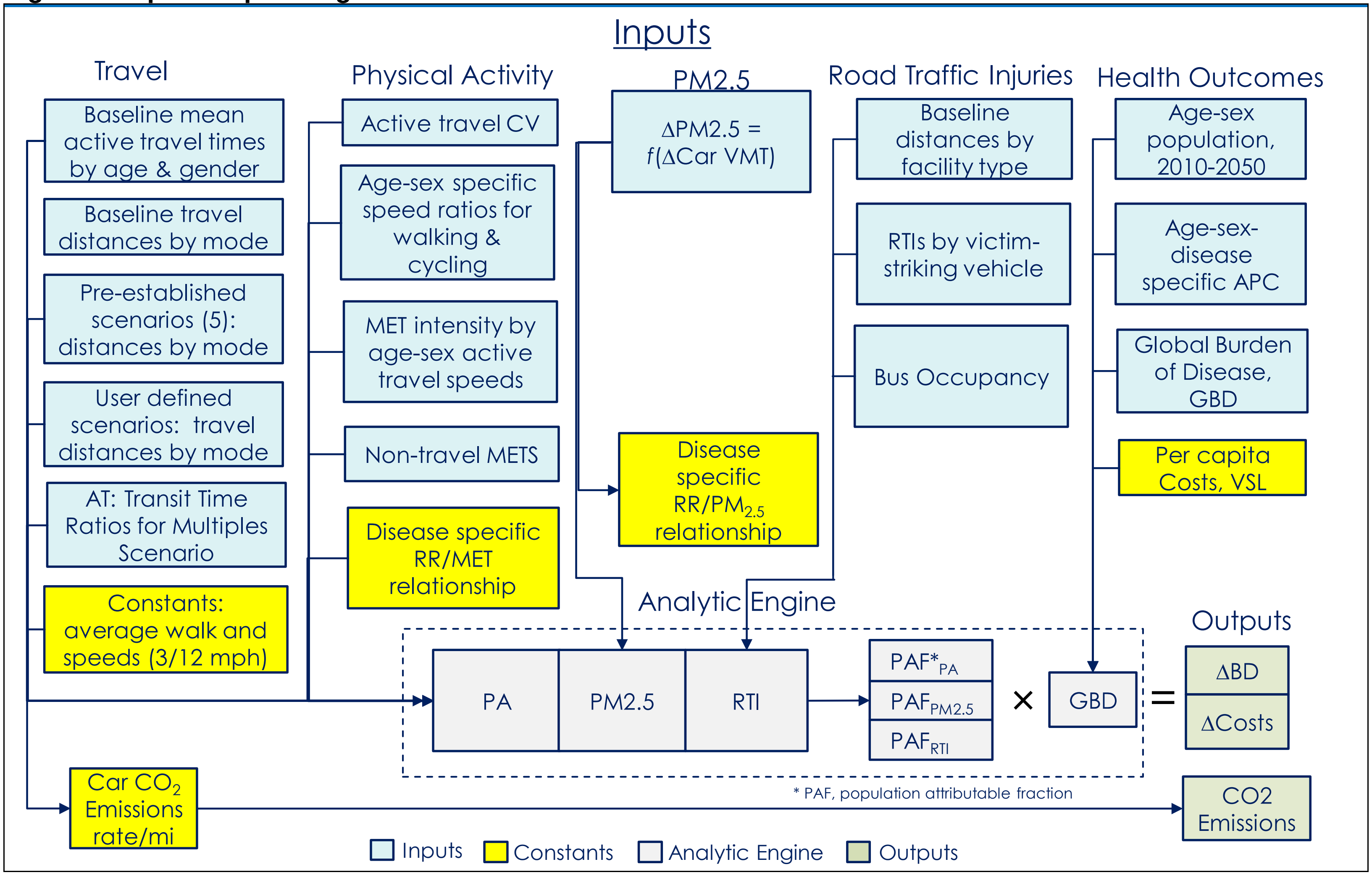
- Quantify the change in the burden of disease for diseases related to physical activity, PM2.5, and road traffic injuries
- Monetize health outcomes, and
- Quantify aggregate and per capita car carbon emissions for baseline and scenario.

Translating Core Equations into R Code

We identified basic R commands that implemented the mathematical equations in Table 5-8. To simplify the programming and to facilitate validation of results with those of spreadsheet ITHIM, we created a "long" version of the analytic engine in R. This version did not contain HTML or interactive components. Scenarios required the manual selection of a scenario, geography, and time period. This version served as a reference. This reference code was integrated into the interface using Shiny reactive commands that account for instantaneous changes in user inputs.

To avoid conflicts in version control of the R/Shiny, we divided the R/Shiny coding by web page with Dr. Maizlish coding the Home, About, Decision Support, and User Support pages, and Mr. Tomari coding the RunITHIM (tool) page. Within R/Shiny programs, comments were copiously applied to explain the major blocks, user-defined functions, and procedures. We adopted coding conventions recommended by R program developers at RStudio for variable naming, case (upper/lower), line length (80 characters), indentation, and spacing.

Figure 6. Input-Output Diagram of California ITHIM



APC, annual percent change; CV, coefficient of variation; PA, physical activity' PM2.5 (fine particulate matter); RTI, road traffic injuries; PAF, population attributable fraction; (G)BD, (global) burden of Disease, RR, relative risks; VSL, value of a statistical life; MET, metabolic equivalent task; mph, miles per hour constants

Table 5. Variables, Inputs, and Functions for the Distribution of MET hrs-wk of Active Travel in the Baseline and Scenario Populations

Variables and strata	
Strata: *i*, age 1 to 8; *j*, gender (M, F); *k*, mode (walk, bike); *i* quintile (1 to 5); b = baseline, s = scenario	
x, per capita mean weekly active travel minutes reported from California Household Travel Survey, CHTS, 2012	
r, age-sex ratio of mean travel times (x) by mode, $r_{ijk} = \frac{x_{ijk}}{x_{F15-29},k}$	
t, population mean active travel time by mode from mean distance, d, and velocity, v, $t_k = \frac{d_{ijk}}{v_k}$ 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, $sd_{ijk} = CV * t_{ijk}$	
P, proportion of population in the *ith-* , *jth* age-gender group	
vc, Age-sex walk velocity adjustment constants, $vc_{ijk} = \frac{v_{ijk}}{v_{..k}}$	
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
$t(b)_{ijk} = f(r_{ijk}, P_{ij}, t_{..k})$ *CV* $MET_{ij,walk} = f[\frac{METS}{v}(Ainsworth), vc_{ij,walk}]$* $MET_{ij,bike} = 6$	$t(s)_{..k} = \frac{d(s)_k}{v_k}$
Program Functions	
Baseline	Scenario
e1: $t(b)_{ijkl} =$ $f(exp[normalinv(\ln(t(b)_{ijk}), \ln(sd(b)_{ijk}, p_l), t_{ij.}])$ e2: $METhrwk(b)_{ijkl} = t(b)_{ijkl} * MET_{ij,k}$	$t(s)_{ijk} = f(r(b)_{ijk}, P_{ij}, t(s)_{..k})^{\dagger}$ $CV(s) = CV(b) - 0.0015429 * [t(s)_{...} - t(b)_{...}]$ $t(s)_{ijkl} =$ $f(exp[normalinv(\ln(t(s)_{ijk}), \ln(sd(s)_{ijk}, p_l), t_{ij.}])$ $METhrwk(s)_{ijkl} = t(s)_{ijkl} * MET_{ij,k}$

Table 6. Equations for Population Attributable Fraction and Burden of Disease for Physical Activity and PM2.5

Variables and strata
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 MET-hrwk$_{ijk}$ = 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 (βs derived from Krewski et al[31])
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 for ischemic heart disease, hypertensive heart disease, and stroke
$$PAF_{ijd} = 1 - (RR_{ijd}^{PA} \times RR_{ijd}^{PM2.5})$$
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
$$\Delta BD_{i,j,d,yr} = PAF_{ij,d} \times BD_{ijd,yr}$$

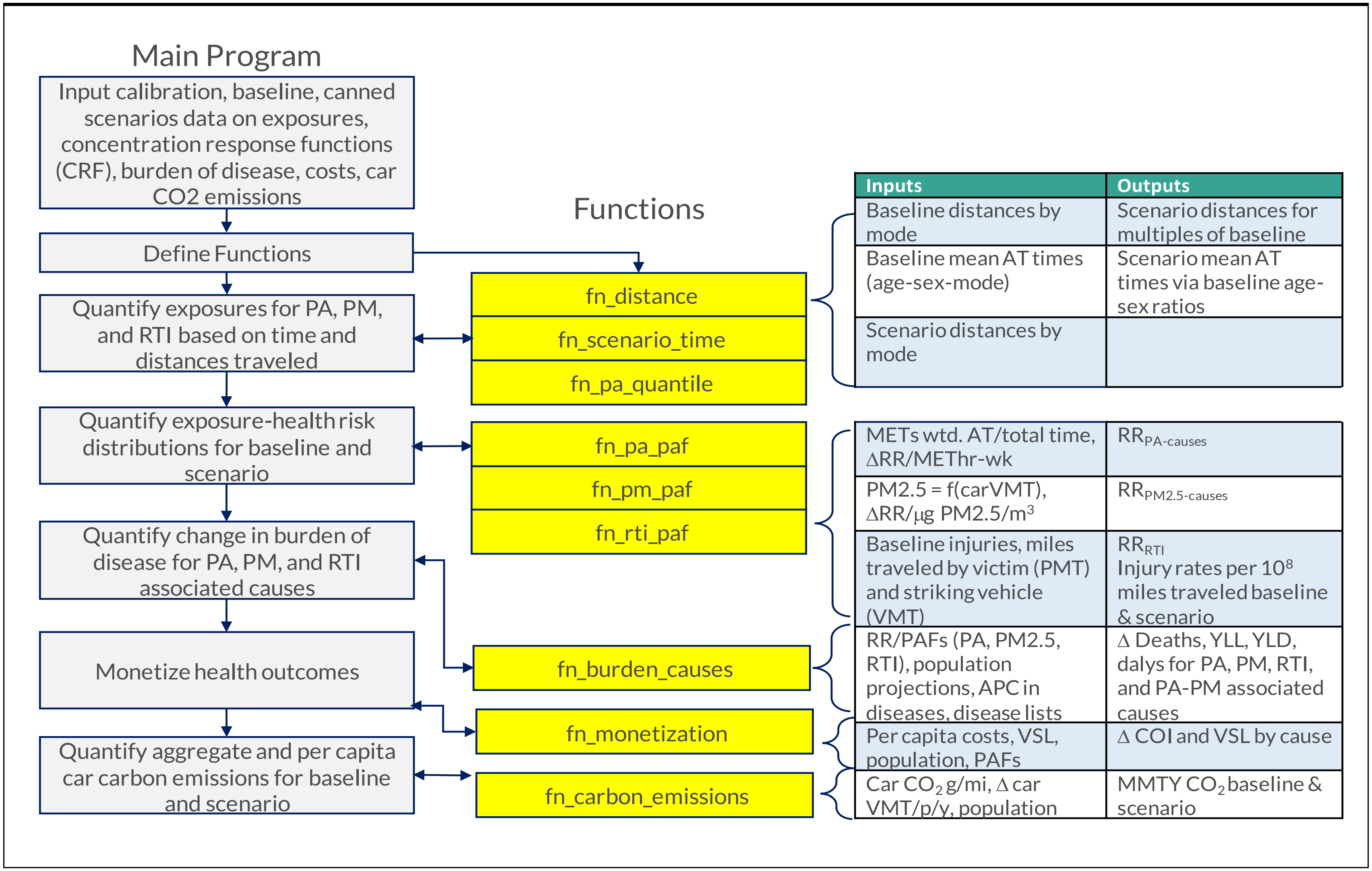
Table 7. Equations for Population Attributable Fraction and Burden of Disease for PM2.5

Variables and strata
Strata: *i*, age 1 to 8; *j*, gender (M, F); b = baseline, s = scenario; d = disease;
A. RR/PAF
$$PAF_{i,j,d} = 1 - e^{\beta_{i,j,d}(PM2.5_{s-} - PM2.5_b)}$$
Where β = 0.008618 (Cardiopulmonary disease) 0.013103 (Lung cancer) 0.009758 (acute respiratory disease in children < 5 years of age)
$PM_{2.5S} = PM_{2.5B} - (m*\Delta\%VMT + y_0)$ Δ%VMT is the percent change of car-driver VMT (B-S)/B M is the slope of the relationship between ΔPM2.5/Δ*Δ%VMT
PAF for ages 0-4, 5-14, 15-29 not calculated (i.e., RR=1)
B. 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
C. Change in the Burden of disease, BD
$$\Delta BD_{i,j,d,yr} = PAF_{ij,d} \times BD_{ijd,yr}$$

Table 8. Equations for Population Attributable Fraction, PAF, and Burden of Disease for Road Traffic Injuries

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

Figure 7. Procedures and Functions for Comparative Risk Assessment



Developmental Server (file transfer protocol)

In addition to desktop application development, we deployed a server version of R/Shiny using the free, open-source software distributed by RStudio (https://www.rstudio.com/products/shiny/shiny-server/). We rented a virtual private server (40GB RAM, 4 core CPU processor, 16 GB mass storage) from a commercial hosting service (BlueHost). The hosting service provided a domain name (cal-ithim.org) and the Linux operating system required to run R. Modest security from automated bot attacks was provided by the host's free SiteLock software. We requested and received a security certificate from Sectigo (https://sectigo.com/legal) for the developmental website https://cal-ithim.org/ithim.

Starting in December 2018, desktop versions of the software application were periodically loaded onto the server for testing. We used free, open source software (WinSCP ver. 5.15.5) to transfer files from our desktops to the server using the SFTP protocol. In addition to the server version of R, the packages for shiny, ggplot2, and several other R packages were also loaded onto the server in order to replicate the functionality of the desktop applications. Testing consisted of comparing the look-and-feel of R/Shiny ITHIM versions run in desktop web browsers with those of the server. We also informally assessed speed of page loading and computational performance.

The server version also was used to demo the website development with our User's Group, who were encouraged to visit the website (https://cal-ithim.org/ithim) before 3rd and 4th User Group meetings, which coincided with previewing the "alpha" (February 5, 2019) and initial beta (March 27, 2019) versions. In response to user feedback, small improvements were incorporated into the developmental website for CARB staff and users to review throughout the summer and fall of 2019.

Downloadable Application

In addition to a server-based version of the R/Shiny application, we conducted a proof-of-concept exercise in which we used free, open source software called Electron (version 5.0.0, https://electronjs.org/), to create an executable version of California ITHIM that users could download from a website and install on their desktop computer without having to download and install R and the packages that support the R/Shiny application. Such an approach has a precedent in CARB's Hotspot Analysis and Reporting Program, HARP (https://www.arb.ca.gov/toxics/harp/harp.htm).

Data Development and Organization

We compiled data inputs from two sources (Figure 6, Tables 9-10):

- Exported and reformatted data from the existing 5 regional Excel spreadsheet ITHIMs (version December 12, 2016)
- De novo data acquisition and analysis for California population projections and car emissions.

Table 9. Source of Calibration Data for R/Shiny California ITHIM

File Name	Description	Spreadsheet ITHIM Worksheet!cells
A. Spreadsheet ITHIM Files		
CalBurdenDisease2010.csv	Age-sex-cause-region specific deaths, yll, yld, dalys	GBDUS
APC_Disease_Rates.csv	Age-sex-cause specific annual change in mortality rates	DiseaseRates
COI2010USD.csv	Cause-specific per capita costs of illness	Costs
ATmean_min_week_age_sex_baseline.csv	Age-sex-region-specific minutes of walking and cycling/p/y by mode	Baseline!H6:I13 (walking), Baseline!N6:O13 (bicycling)
bike_walk_cv.csv	Region-specific coefficient of variation for mean active travel (mi/p/y)	Calibration!V360
METminWalk_Bike.csv	Age-sex-mode (walk/bike) specific MET weights for active travel	Baseline!AD6:AE13 (walking), Baseline!AF6:AG13 (bicycling)
nonTravelMETS.csv	Age-sex-quintile specific min/p/w of non-travel METs	non travel METS
Distances_mi_year_baseline.csv*	Region-specific travel miles/p/y by mode for 2010 baseline year	See Table 10
Distances_mi_yr_scs.csv*	Region-specific travel miles/p/y by mode reported in MPO EIRs	See Table 10
Distances_mi_yr_strip.csv*	Region-specific travel miles/p/y by mode substituting car trips	Manually transcribed from R program
Distances_mi_yr_ussg.csv*	Region-specific travel miles/p/y by mode with AT median 150 min/p/w	Visions persons:K59:K70 (inputs) K35:K42 (outputs) mean distances corresponding to What If calculator run for 50:50 (walk:bike) time for total of 21.4 median min/p/d)
Baseline_distance_by_facility_type.csv	Region-specific percentage of VMT by mode and facility type	Calibration!T364:T372
WalkBikeTransitRatios.csv	Region and mode (bike/walk)-specific ratio of transit travel time (min/p/y)	Visions persons!C84:C97
Bus_occupancy.csv	Region-specific bus occupancy	Calibration!T373
ParameterDefaults.csv	Default constants (e.g., walk, speed, bike speed, VSL, etc.)	Baseline!V15 (walk), Baseline!AB15 (bicycle)
age_sex_region2010.csv	Age-sex-region-population proportions for baseline year 2010	Calibration!T51:T66
PA_RR.csv	Disease-specific RR per METhr-wk	Phy activity RRs!C4:O4

* incorporated into tools_file\default_narratives2019_07_10.csv; p/y, per person per year; p/w, per person per week

Table 9 (continued). Source of Calibration Data for R/Shiny California ITHIM

File Name	Description	Method or File
rti_baseline.csv	Region-severity-facility specific RTIs by striking and victim mode for baseline year	Baseline injuries
PM25_RR.csv	Disease-specific RR per mg/m3 of PM2.5	air pollution!3:4 (for lung cancer and acute respiratory illnesses in children)
B. New Data Files		
DiseaseRiskAdjuster.csv	Age-sex-cause specific adjustment factor to population subgroup (equity analysis)	Manually set RR to 1 for age-sex-disease cells
CO2g_mi.csv	Region-specific grams of CO2 per car mile traveled	Batch file (EMFAC2017_2010_2050CO2.R) analysis of EMFAC2017 downloads from http://www.arb.ca.gov/emfac/2017/
PM25CARB2010_2050.csv	Region-specific change in PM2.5 with change in car VMT	Manual calculations from ARB updated Incidence per Ton ARB for NOx and Diesel PM (population2010-2050PM25_IPT2019-03-08.xlsx)
user_scenario.csv	Region-specific travel miles/p/y by mode and percent VMT by mode and facility type	Provided template for users (TestScenarioUploadData2018-11-09.csv)
age_sex_region_county2010-2050.csv	Age-sex-county population projections in 5 calendar year bands from 2015-2050	Batch file (Pop_Projections_20180731.R) analysis of California Department of Finance P-2 file aggregated by age, sex, county in 5 calendar increments from 2015 to 2050

Table 10. Data Extraction for Travel Patterns in Baseline and Preferred Sustainable Communities Strategy from Regional ITHIM Excel Spreadsheets

Excel Spreadsheet (Region*)	Topic: Worksheet	Cells
ITHIM_California2016-12-12MTC_Trends.xlsx (San Francisco Bay Area)	Walk: Scenario Data (2010_05_03) Bike: Calibration Data (CHTS2012) Car Driver: Scenario Data (2010_05_03) Car Driver: Scenario Data (2010_05_03) Bus: Calibration Data (2010_05_03) Rail: Scenario Data (2010_05_03) Motorcycle: Calibration Data (CHTS2012) Truck: Scenario Data (2010_05_03): Daily distances multiplied by 365 for yearly total; 11 decimal digit precision to avoid rounding error	U176 T42 U170 U171 T46 U175 T48 T187:T189 (daily distance local, arterial, highway)/ 2010 population U190
ITHIM_California2016-12-12SJV_Trends.xlsx (San Joaquin Valley)	Walk: Scenario Data (FC14_BASE) Bike: Calibration Data (CHTS2012) Car Driver: Scenario Data (FC14_BASE) Car Driver: Scenario Data (FC14_BASE) Bus: Calibration Data (FC14_BASE) Rail: Scenario Data (FC14_BASE) Motorcycle: Calibration Data (CHTS2012) Truck: Scenario Data (FC14_BASE):	U9 from CHTS U9 from CHTS U14 U15 U12 U11 T48 T20:T22 (daily distance local, arterial, highway)/ 2010 population U16
ITHIM_California2016-12-12SACOG_Trends.xlsx (Sacramento Area)	Walk: Calibration Data (CHTS2012) Bike: Calibration Data Car Driver: Calibration Data (CHTS2012) Car Driver: Calibration Data(CHTS2012) Bus: Calibration Data (CHTS2012) Rail: calibration Data (CHTS2012) Motorcycle: Calibration Data (CHTS2012) Truck: Scenario Data (CSTDM):	T43 T42 T44 T45 T46 T47 T48 T49

Table 10 (Continued). Data Extraction for Travel Patterns in Baseline and Preferred Sustainable Communities Strategy from Regional ITHIM Excel Spreadsheets

Excel Spreadsheet (Region)*	Worksheet	Cells
ITHIM_California2016-12-12SoCal_Trends.xlsx (Southern California)	Walk: Scenario Data (Baseline2010) Bike: Scenario Data (baseline) Car Driver: Scenario Data (Baseline2010) Car Driver: Scenario Data (Baseline2010) Bus: Scenario Data (Baseline2010) Rail: Scenario Data (Baseline2010) Motorcycle: Calibration Data (CHTS2012) Truck: Scenario Data (Baseline2010): :	U9 (from CHTS) U10 (from CHTS) U14 (from SCAG ABM) U15 (from SCAG ABM) U12 (from SCAG ABM) U11 (from CHTS) T48 (from CHTS) T20:T22 (daily distance local, arterial, highway)/ 2010 population U16
ITHIM_California2016-12-12SANDAG_Trends.xlsx (San Diego County)	Walk: Calibration Data (CHTS2012) Bike: Calibration Data Car Driver: Calibration Data (CHTS2012) Car Driver: Calibration Data(CHTS2012) Bus: Calibration Data (CHTS2012) Rail: calibration Data (CHTS2012) Motorcycle: Calibration Data (CHTS2012) Truck: Scenario Data (CSTDM):	T43 T42 T44 T45 T46 T47 T48 T49 (daily distance local, arterial, highway)/ 2010 population)
(California)	California total is population-weighted average using US Census 2010 population estimates SF Bay Area: 7,150,739; San Joaquin Valley: 3,971,659; Sacramento Area: 2,316,019;Southern California: 18,051,534; San Diego County: 3,095,313; Total: 34,585,264 Calibration Data	T50

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

California ITHIM required 24 CSV-formatted input files, not including the optional user uploaded scenario data file.

Specific rows and columns of calibration and scenario data were manually exported from regional Excel spreadsheets (Tables 9-10) to create 19 individual CSV-formatted output files with a region identifier, where appropriate. The California total for region-stratified files was manually created using regional population weights with Excel.

Four input files were newly created for the R/Shiny version of ITHIM (Table 9). Age-sex-county-region specific in 5 calendar year bands, 2015 to 2050 (California Department of Finance, P2 file) replaced an ITHIM spreadsheet with age-sex counts by region for 2010 and 2040. Likewise, VMT-weighted CO_2 emissions per car mile traveled by fuel type (gas, diesel, electric) was calculated at 5-year intervals between 2010 and 2050. This replaced an ITHIM spreadsheet for 2 years (2010, 2040).

To facilitate equity analyses, a new CSV file (DiseaseRiskAdjuster.csv) was created by following the region-age-sex-disease specific file, the California burden of disease file (CalBurdenDisease2010.csv). A column for risk adjustment was added and set to 1. This file is a place holder for users with the knowledge and skills to derive a multiplier from vital statistics or other data to raise of lower the burden of disease for a specific population subgroup (e.g. race/ethnicity, income, etc.).

Baseline and Scenario Data Files

The R/Shiny ITHIM incorporates one baseline and 8 alternative travel scenarios (Table 11). Of the 8 scenarios, 3 were generated from pre-existing data of the spreadsheet versions of ITHIM and 5 were internally generated by the software application. CARB's Scoping Plan Update and the Caltrans Strategic Management Plan are based on multiplying the baseline levels of walking, bicycling, and transit by pre-set constants (4, 9, 4 and 2, 3, 2, respectively). The scenario "Baseline Multiples" allows user input for these active travel modes. Fixed time for walking and cycling also receives user inputs of mean weekly minutes per person and converts travel times to distances by which car travel is reduced. Low Carbon Driving does not change travel distances from the baseline, but accounts for reduced $PM_{2.5}$ and carbon emissions using a constant reduction of 33.5% of the baseline.[32]

Infographic Comparison Data

Data for the low carbon driving (LCD) and US Surgeon General's Recommendation were pre-rendered from model runs varying calendar period year in 5-year increments (2010 to 2050) and geography (5 MPO regions and California), using the long version of the analytic engine (PA_PM_RTI_costs_CO2_functions2019-01-7.R).

Data file names, variables, definitions, coding levels, and primary data sources will be presented in the data organization section below.

Table 11. Baseline and Scenarios in California ITHIM

Scenario Name	Description	Source
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.	California Household Survey, 2012 (walk, bike, motorcycle); MPO travel demand models/EIRs for car, bus, rail, truck VMT
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.	Calculated as a multiple of 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.	Calculated as a multiple of 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.	MPO travel demand models/EIRs for car, bus, rail, truck VMT [2]

* Internally generated as a multiple of baseline

Table 11 (continued). Baseline and Scenarios in California ITHIM

Scenario Name	Description	
U.S. Surgeon General Recommenda-tions (USSG)	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.	Spreadsheet ITHIM What If calculator set for a median of 21.4 min/p/d of walking and cycling (50:50 split)
Baseline Multiples*	This is a "What-If" Scenario in which the user 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 the user to input any multiple of the regional baseline average of walking, cycling, or transit.	Calculated as a multiple of baseline from user specified inputs
Fixed Time*	This is a "What-if" scenario allows the user to specify the average weekly minutes of walking and cycling for transport.	Calculated from user specified inputs
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).	Calculated from California Household Travel Survey, 2012
Low Carbon Driving (LCD)*	This scenario 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.	Based on Lutsey[32]
User Upload and Equity Analyses	Users who have access to a travel or land use model, can assess the health impacts of user-specified 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.	Calculated from user specified inputs

Air Pollution Data

The fourth new file described the relationship between ambient $PM_{2.5}$ concentrations as a function of changes in car emissions due to different car travel distances in baseline and scenarios. However, it was the product of a multistep process that began by comparing methods used in California ITHIM and CARB in carrying out comparative risk assessment.

Spreadsheet ITHIM used the results of a chemical transport model (called Multiple Pollutant Evaluation Method, MPEM) developed by the Bay Air Quality Management in 2010. Emissions in tons per day from primary and secondary constituents of $PM_{2.5}$ from cars were estimated by the Emission Factor (EMFAC) Model 2007 and were inputs to the MPEM model along with other mobile and stationary sources. Variations in car emissions were based on graded changes in car VMT, and a linear relationship was derived for the percent change in car VMT and quantitative change in ambient air levels of $PM_{2.5}$.(Δ μg $PM_{2.5}$-m^3 /Δ Percent Car VMT).

The CARB method followed that recommended by the U.S. EPA [33, 34] based on change in mortality incidence per ton of constituents of $PM_{2.5}$.

The UCD Team and CARB scientists first evaluated whether their two methods generated similar results for a hypothetical 0.1 $\mu g/m^3$ change in ambient $PM_{2.5}$ levels the same basin using similar estimates of the concentration response function for cardiorespiratory disease [(ΔRR/(Δ $\mu g/m^3$), 0.01293] [31] and age-sex specific populations. As an *a priori* criteria, a difference in mortality estimates < 10% was good agreement between methods. The methods produced very similar mortality estimates for the Bay Area air basin in 2010 (18.7 CARB vs. 17.8 ITHIM).

After establishing the compatibility of the methods, CARB scientists provided incidence (of cardiopulmonary disease mortality) per ton of diesel PM and oxides of nitrogen (NO_x) for air basins that corresponded to the geographic regions used in ITHIM. Both methods predict mortality incidence as either an emission or ambient air concentration, so they may be equated for equivalent numbers of deaths. Through this equivalency, a formula was derived to express incidence per ton of emissions, first as incidence per $\mu g/m^3$, and then as a function of emissions per car mile traveled. The sequence of steps and the mathematical formulae are presented in Table 12.

Table 12. Conversion of Change in Incidence per Ton to Change in Ambient PM2.5 per Percent Car VMT

Step	Formula
1. Population attributable fraction, PAF, as a function of change in ambient PM2.5 concentrations, Δx = x0 - x1, and the concentration-response function coefficient, β	$PAF = 1 - e^{\beta(x_0 - x_1)}$
2. Mortality incidence as a function of PM2.5 and precursor emissions in tons per day, TPD, of pollutant i (PM2.5, NO_x)	$Incidence\ (deaths) = \sum_{i}^{n} c_i \times TPD_i$
3. Change in incidence as a function of the PAF	$PAF \times BD = \Delta BD = \Delta\ Incidence\ (annual\ deaths)$
4. Change in $PM_{2.5}$ concentration per death	$\Delta PM_{2.5} = \frac{\ln(1 - \frac{1}{BD})}{\beta}$
5. Equivalency ratio (per death) of PM2.5 concentration and emissions	$Ratio_i = \frac{\Delta PM_{2.5}}{\Delta TPD_i} = \frac{\frac{\ln(1 - \frac{1}{BD})}{\beta}}{\frac{1}{c_i}}$
6. $PM_{2.5}$ ambient concentration as a function of emissions of pollutants in tons per day	$\Delta PM_{2.5} = Ratio_{DPM} \times \Delta TPD_{direct\ car\ PM2.5} + Ratio_{NOx} \times \Delta TPD_{car\ NOx}$
7. $PM_{2.5}$ ambient concentration as a function of 1% change in car emissions (1% change in car VMT)	$\Delta PM_{2.5} = Ratio_{DPM} \times (0.01 * \Delta TPD_{direct\ car\ PM2.5}) + Ratio_{NOx} \times (0.01 * \Delta TPD_{car\ NOx})$

To derive the ΔPM2.5/Δcar VMT relationship, we ran EMFAC2017 emissions estimates of $PM_{2.5}$ (including tire and brake wear and NOx) at 5-year intervals from 2010 to 2050 for California air basins. These data were entered into an Excel spread sheet, whose cells were programmed with equations 6 and 7 (Table 12). The calculated values were formatted by California region and year in a CSV file (PM25CARB2010_2050.csv).

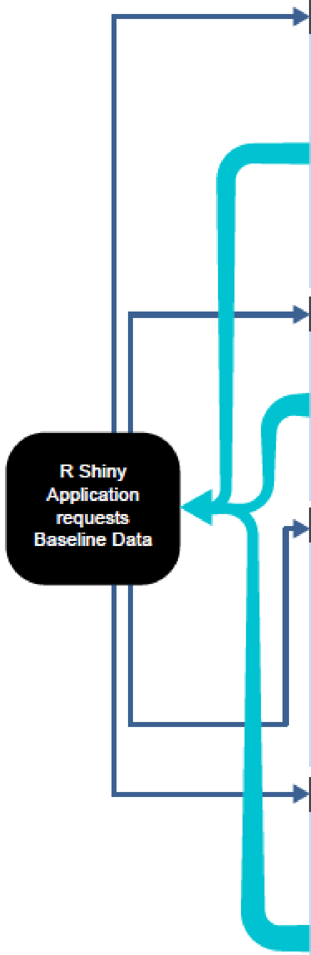
Data Organization

We considered several options to organize and store the data inputs (Figure 8) for both software development and the deployment. One option – a centralized repository using a relational database – had the advantage of controlled versioning of master files for distribution. However, using relational databases requires skills, staff time and additional software that had to be supported by CARB's Office of Information Services. A second option – a folder with individual .csv (flat) files – did not require additional software applications. After the application is deployed, most input data files are updated at 1 to 5 year intervals. As long as the files and their contents were well documented, we decided that creating a versioned file folder containing flat files would be an effective data repository along with detailed metadata.

<u>Meta-Data Dictionary</u>

To document and perform version control on data files, we created a meta-data dictionary (Figure 9). The dictionary was organized by module (physical activity, air pollution, road traffic injury), categories of information within modules, data files, and variables within data files along with their definition, format, code list, source, version, etc. The dictionary was implemented in MS Access, and queries were written for file lists (Table 13) with attributes (Table 14).

Figure 8. Options for Data Storage for Application Development



Options	Pros	Cons	Notes
MySQL — ODBC Access a separate MySQL server directly using an Open Database Connection (ODBC)	More widely accessible for developers (we all have access to same data). Less corruption issues as compared to flat files (i.e. csv).	Extra server would have to be established (more costs). More complicated maintenance (due to MySQL knowledge). In other words, data would be more difficult to update. As SQL queries would originate from R code, development of R code would integrate this layer of complexity. Dependent on R package ODBC.	**Scripts**: R code (with SQL code embedded)
csv Pull data in from a csv (Comma Separated Values) file saved with the R code.	Simple management.	More easily corrupted file format. May lead to version issues due to local storage.	**Scripts**: simple R code.
MySQL to csv Make a request to a script on the CARB server to produce a csv from an MySQL database.	More widely accessible for developers (we all have access to same data). Less corruption issues. R code more easily loads data using flat files.	Extra server would have to be established (more costs). More complicated maintenance (due to script file/MySQL knowledge). In other words, data would be more difficult to update. Additional script (compare against MySQL ODBC above).	This script would not run frequently. The script would only be run in circumstances where there appears to be errors or changes were made. **Scripts**: R code (simple), Server-side script to access MySQL server, generate a csv, and check data integrity.
SQLite Directly open a connection with an SQLite file stored on the CARB server through R.	Fairly simple management system. There are less corruption issues. SQLite is designed to be used for local data storage for individual applications (like this project).	The data is slightly more difficult to change than csv (but no knowledge of SQL is necessary to update data). Slightly more difficult for code develop-ment as local storage may lead to version issues (but careful development protocol should make this trivial). Does not work on shinyapps.io. (Possibly) dependent on R Package RSQLite.	We could also write a script that produces a csv like in the above example. **Scripts**: simple or more complicated R code, possibly a second piece of script to produce the csv file and check data integrity.

Figure 9. Meta Data Dictionary

Relationships between files and variables within files

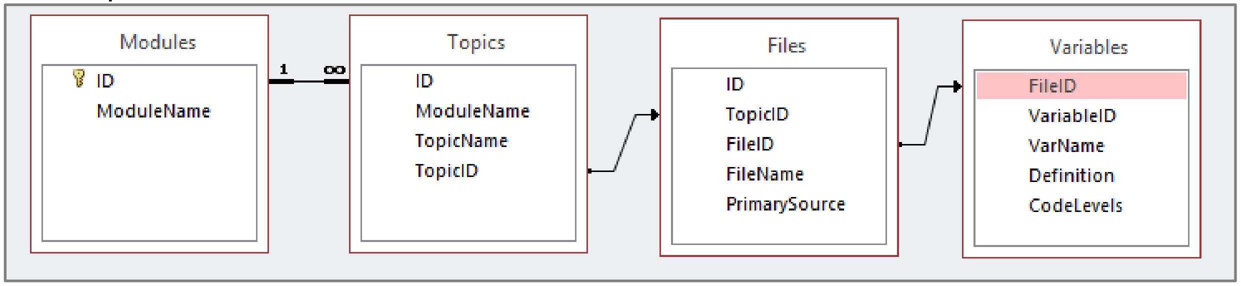


Table of Files

Module_Files | Variables_by_File

ModuleName	TopicName	FileName	PrimarySource
Burden of Disease	Deaths, DALYs	CalBurdenDisease2010_2040.csv	Institute for Health Metrics and Evaluation
PA	Active Travel Times	bike_walk_mean_min_week_scs.csv	Published EIRs of MPOs
PA	Active Travel Times	USSG_ATtimes2.csv	Preprocessed by NM
PA	Active Travel Times	ShortTrips.csv	CHTS2012
PA	Active Travel Times	ATmean_min_week_age_sex_baseline.csv	CHTS2012
PA	CV AT Time	bike_walk_cv.csv	CHIS2009, NM processed
PA	MET Intensity	METminWalk_Bike.csv	JamesWoodcock, 2011
PA	NonTravel METS	nonTravelMETS.csv	CHIS 2009, SAS program Item4_CHIS2009_PA_Quintiles_SD8-30-13Cor
PA	Travel Distances	Distances_mi_yr_ussg.csv	Baseline Motorized modes + 75 med min bike/walk converted to mear
PA	Travel Distances	Distances_mi_year_baseline.csv	CHTS2012, MPO TDMs
PA	Travel Distances	Distances_mi_yr_strip.csv	CHTS2012
PA	Travel Distances	user_scenario.csv	User-defined
PA	Travel Distances	Distances_mi_yr_scs.csv	MPO TDMs, AT MPO EIR relative increase from baseline
PA	Dose-response relationship	PA_RR.csv	JamesWoodcock2010
PM25	Dose-response relationship	PM25_RR.csv	Krewski et al 2009, via Bart Ostro, 2010
PM25	VMT-Ambient PM2.5 Relationship	PM25CARB2012.csv	EMFAC, Airshed models
Population	Population	age_sex_region2010.csv	USCensus_2010_SF1_QTP1
RTI	Roadway Type	Baseline_distance_by_facility_type.csv	MPO and California Statewide travel demand models
RTI	Baseline Injuries by Mode, Facility, and Severity	rti_baseline.csv	SWITRS, 2006-2010

Table of Variables within Files

Module_Files | Variables_by_File

ModuleName	TopicName	FileName	VarName	Definition	CodeLevels
Burden of Disease	Deaths, DALYs	CalBurdenDisease2010_2040.csv	Region	California and 5 MPOS regions	California; SF Bay Area; San Joaquin Valley; Sacramento Area; Southern Calif
Burden of Disease	Deaths, DALYs	CalBurdenDisease2010_2040.csv	Year	5-year annual average of projected	2015-2019, 2020-2024, 2025-2029, 2030-2034, 2035-2039, 2040-2044, 2045
Burden of Disease	Deaths, DALYs	CalBurdenDisease2010_2040.csv	Cause	Diagnostic Category	All Causes, Acute Respitatory Infections, Breat Cancer, Colon Cancer, demen
Burden of Disease	Deaths, DALYs	CalBurdenDisease2010_2040.csv	Sex	Gender	1=M, 2=F
Burden of Disease	Deaths, DALYs	CalBurdenDisease2010_2040.csv	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+
Burden of Disease	Deaths, DALYs	CalBurdenDisease2010_2040.csv	pop	Population at projected year	numeric
Burden of Disease	Deaths, DALYs	CalBurdenDisease2010_2040.csv	deaths	Number of projected deaths	numeric
Burden of Disease	Deaths, DALYs	CalBurdenDisease2010_2040.csv	yll	Years of life lost	numeric
Burden of Disease	Deaths, DALYs	CalBurdenDisease2010_2040.csv	yld	Years living with disability	numeric
Burden of Disease	Deaths, DALYs	CalBurdenDisease2010_2040.csv	dalys	Disability life years	numeric

Table 13. Calibration and Scenario data File Names, Descriptions, and Primary Source by Category 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_SD 8-30-13Confidential.sas
Exposure	Distances_mi_year_baseline.csv	Region-specific travel miles/p/y by mode for 2010 baseline year	CHTS2012, MPO TDMs
Exposure	Distances_mi_yr_scs.csv	Region-specific travel miles/p/y by mode reported in MPO EIRs	MPO TDMs, AT MPO EIR relative increase from baseline
Exposure	Distances_mi_yr_strip.csv	Region-specific travel miles/p/y by mode substituting car trips	CHTS2012
Exposure	Distances_mi_yr_ussg.csv	Region-specific travel miles/p/y by mode with AT median 150 min/p/w	Baseline Motorized modes + 75 med min bike/walk converted to mean and then 3 and 12 mph speed
Exposure	Baseline_distance_by_facility_type.csv	Region-specific percentage of VMT by mode and facility type	MPO and California Statewide travel demand models

Exposure	PM25CARB2012.csv	Region-specific change in PM2.5 with change in car VMT	EMFAC, Air shed models
Exposure	user_scenario.csv	Region-specific travel miles/p/y by mode and percent VMT by mode and facility type	User-defined
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_county 2010-2050.csv	Age-sex-county population projections in 5 calendar year bands from 2015-2050	USCensus_2010_SF1_QTP1, CaDoF_2015-2050
Risk	PA_RR.csv	Disease-specific RR per METhr-wk	JamesWoodcock2010
Risk	PM25_RR.csv	Disease-specific RR per mg/m3 of PM2.5	Krewski et al 2009, via Bart Ostro, 2010
Risk	rti_baseline.csv	Region-severity-facility specific RTIs by striking and victim mode for baseline year	SWITRS, 2006-2010

Table 14. 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 14. Variable Names, Definitions, and Coding Levels of 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 14. Variable Names, Definitions, and Coding Levels of 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, 7400000
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 14. 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 14. Variable Names, Definitions, and Coding Levels of Calibration ND Scenario Data Files, California ITHIM (cont'd)

File Name	Variable Name	Definition	Code Levels
Distances_mi_year_baseline.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, CarDriver, CarPassenger, Bus, Rail, Motorcycle, Truck
	Baseline	Per capita mean miles/p/yr	TBD edit checks specific to mode
Distances_mi_yr_scs.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, CarDriver, CarPassenger, Bus, Rail, Motorcycle, Truck
	Scenario	Per capita mean miles/p/yr	TBD edit checks specific to mode
Distances_mi_yr_strip.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, CarDriver, CarPassenger, Bus, Rail, Motorcycle, Truck
	Scenario	Per capita mean miles/p/yr	TBD edit checks specific to mode
Distances_mi_yr_ussg.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, CarDriver, CarPassenger, Bus, Rail, Motorcycle, Truck
	Scenario	Per capita mean miles/p/yr	TBD edit checks specific to mode

Table 14. Variable Names, Definitions, and Coding Levels of Calibration and Scenario Data Files, California ITHIM (cont'd)

File Name	Variable Name	Definition	Code Levels
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 ug/m3 PM2.5)	CVD, 0.008618; Lung Cancer, 0.013102826; respiratory dis, 0.008618; Acute resp infections, 0.009758033
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	

Table 14. Variable Names, Definitions, and Coding Levels of Data Files, California ITHIM (cont'd)

File Name	Variable Name	Definition	Code Levels
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
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

Table 14. Variable Names, Definitions, and Coding Levels of Data Files, California ITHIM (cont'd)

File Name	Variable Name	Definition	Code Levels
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
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	>=0, upper limit TBD
	bike	Number of injuries, bike striking mode	>=0, upper limit TBD
	bus	Number of injuries, bus striking mode	>=0, upper limit TBD
	car	Number of injuries, car striking mode	>=0, upper limit TBD
	truck	Number of injuries, truck striking mode	>=0, upper limit TBD
	motorcycle	Number of injuries, motorcycle striking mode	>=0, upper limit TBD

Table 14. Variable Names, Definitions, and Coding Levels of Data Files, California ITHIM (cont'd)

File Name	Variable Name	Definition	Code Levels
	NOV	No other vehicle involved in collision	>=0, upper limit TBD
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)	>=0

Testing Procedures

Data Validation

We performed several types of testing on the software application as a desktop application and on the developmental server. First was data validation. This was carried out by comparing the outputs of the San Francisco Bay Area spreadsheet version of ITHIM against its R/Shiny counterpart. This region was chosen because, unlike other regions, air pollution data were available. Validation testing compared the numerical values of outputs (tables) given identical data input files. We examined R data frames from the application and blocks of Excel spreadsheet cells for the same functional component of the comparative risk assessment (Figure 7). To simplify testing, we used the long version of the analytic engine and manually changed scenarios, geographies, and time periods. Each scenario was tested. Testing was co-extant with R code development and debugging because any discrepancies we found were traced back to the developmental R code and corrected before testing the next functional component. The debugged CRA functions in the long engine then were incorporated into the R/Shiny code (app.R) that generated the California ITHIM website. We again examined the website tables against their spreadsheet counterparts for fidelity.

Performance

The second type of testing was based on the performance of the website itself. We examined whether the HTML and CSS was translated properly for popular web browsers that included the latest versions of Chrome, Firefox, Internet Explorer 14, Edge, Opera, and Safari). We also examined whether content shifted and became difficult to read as the browsers resized pages from 50% to 200%. For the developmental server version, we did a qualitative assessment of response times for generating the summary report, infographic, tables, and graphs after users change selection of scenarios, geography, or time period. We also considered the speed of page loading, especially for content with banner photographs. Given the modest configuration of the developmental server, we did not find excessive delays (>5 seconds) in response time. We observed some pages loaded slowly, but that this was not a significant impediment.

Accessibility

We also tested the website for accessibility using the Web Accessibility Checklist, published by the California Department of Rehabilitation (https://www.dor.ca.gov/Content/DorIncludes/documents/Ab434/Web-Accessibility-Checklist.docx.) The checklist follows recommendations in the Web Content Accessibility Guideline (WCAG, http://www.w3.org/TR/WCAG21/). We submitted the website to an open source, free accessibility checker (https://www.alumnionlineservices.com/scanner/), which provided feedback on areas for improvement. We made suggested changes and re-ran the checker.

RESULTS

The results of this project are a software application and supporting materials. Previous sections described how we produced the software application and its data. This section describes the project deliverables, which are reproduced in Table 15 from the technical proposal of this project. In several cases, readers are directed to the developmental website of California ITHIM (https://cal-ithim.org/ithim) where the software can be seen and experienced directly. For readers without access to the internet, Chapter 2 of the *User's Guide and Technical Manual* (Appendix C) provides screenshots of the webpages and step-by-step procedures on how to use the model to conduct health impact analyses

Website

The R/Shiny application (app.R) has approximately 8000 lines of R/Shiny code and generates the California ITHIM website, which is accessible on a developmental server (https://cal-ithim.org/ithim). The software can be packaged as downloadable desktop application. The website has 16 pages, 57 photographs and icons, three video tutorials, and a template for 1 summary report, 1 infographic, 37 tables (including 22 detailed disease-specific tables), 35 graphs (including 22 detailed disease-specific graphs), 94 links to the scientific literature and other websites as resources. The outputs accommodate user choices of 8 scenarios, 36 geographic entities (California, 5 regions, 30 counties), and 9 time periods (2010 to 2050 in 5-year increments). Outputs can be saved as CSV files or PDFs (HTML).

Structured Database

We created a data repository with 24 CSV-formatted data files (Table 13-14). The data are documented with a meta-data dictionary and are downloadable from the developmental server (https://cal-ithim.org/ithim/#Data, ITHIMCalibrationData.zip).

Utility to Upload Data

The RunITHIM tool page allows users to select the option for uploading data. Multiple baselines and scenarios can be uploaded from the same file, and dialogue boxes allow users to select their own baseline, business-as-usual, and alternative scenarios.

User-Specified Analyses

The RunITHIM tool page allows users to select a range of scenarios from pick lists. These include agency goals and user-specified What if scenarios based on multiples of the 2010 baseline or absolute levels of active travel time for walking, bicycling, and transit.

Reports, Tables, Graphs, and Exportable Files

The RunITHIM tool page allows users to select 4 different output formats: summary report, infographic, tables and graphs. Users can select among three levels of detail (summary, medium, high) to view tables and graphs.

Tutorials and Decision Support

The website incorporates three 6 to 8 minute video tutorials, and 6 webpages dedicated to decision and user support. The user support materials also include a quick navigation guide, a detailed user manual, and slides for a self-guided workshop. Decision support pages describes over 50 policies, best practices, case studies, projects, and other resources that assist real-world implementation.

Easily Maintained and Updated

The architecture of the software application allows CARB staff to edit CSV files (webtext.csv, webphotoimage.csv) to modify website text, hyperlinks, photos, and other images. This obviates the need to alter the R/Shiny code itself. Likewise, each data file (Table 11), can be replaced by a file of identical format, but with updated data.

Operable on Different Platforms

We have demonstrated that the application can run in three different environments: 1) the RStudio IDE, 2) LINUX-based server, and 3) downloadable desktop application. This provides CARB a range of options for deployment.

Administrative Reporting

We have provided quarterly progress reports and this report in fulfillment of our contract. The final research seminar was scheduled for November 13, 2019.

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Table 15. Deliverables for Updating the Integrated Transport and Health Impact Model

Deliverable	Status/Delivery Location
1. An ITHIM tool that is easy to understand, use, and update on an accessible platform that preserves and enhances the functionality of the current spreadsheet version and will be compatible with more methodologically advanced and resource intensive versions of ITHIM currently under development	• The website (https://cal-ithim.org/ithim) integrates analytic engine, interface, data, user support and is compatible with versions under development
2. Provide a Statewide structured and standardized database from the pre-existing and preprocessed calibration data on transportation and health, including that for air pollution provided by CARB, to facilitate statewide, regional, and county and possibly sub county analyses that can be maintained and updated with more current calibration data stored by CARB and by CDPH.	• Data are available at https://cal-ithim.org/ithim/#Data (ITHIMCalibrationData.zip). The metadata dictionary for the files and variables within files are described in the User's Guide and Technical Manual (https://cal-ithim.org/ithim/ITHIM_manual_draft.pdf), pages 45-56.
3. Develop a user-friendly interface and utility to upload calibration and scenario data based on advisory group(s) recommendations,	• The user data upload (https://cal-ithim.org/ithim/#RunITHIM) function is incorporated into the scenarios picklist
4. Develop a user interface that allows users to configure ITHIM for their specific analyses, with the assistance of the broad-based advisory group	• The interface allows users to select specific scenarios, geographies, and time periods using pre-established scenarios or user-defined scenarios (https://cal-ithim.org/ithim/#RunITHIM)
5. Develop reports that incorporate tables, graphs, and exportable files that summarize the results of analyses and that meet the needs of users with a range of technical abilities	• The RunITHIM page (https://cal-ithim.org/ithim/#RunITHIM) has radio buttons for users to select tables, graphs, and exportable files that summarize the results of analyses and level of detail (summary, medium, high)

Table 15. Deliverables for Updating the Integrated Transport and Health Impact Model (cont'd)

6. Provide tutorials and decision support information so that users can contextualize the results of analyzes and link their scenarios to policies, best practices, case studies, projects, and other resources that will assist their real-world implementation.	• The User Support (https://cal-ithim.org/ithim/#UserSupport) pages has video tutorials, a quick guide, User's Guide & Technical Manual, and self-paced workshop to learn about the principles and practice of ITHIM. The Decision Support pages (https://cal-ithim.org/ithim/#Health) has information on contextualizing the results and the pages on Strategies, Evidence, Data & resources list over 50 policies, best practices, case studies, projects, and other resources that assist real-world implementation.
7. Provides a tool that will be easy and clear to maintain, modify, and update with more current calibration data through easy-to-follow documentation, batch computer code, and in-person training. The training provided for CARB and optional for CDPH will help develop competency so staff on their own (without UCD assistance) can process raw (disaggregated) calibration data from their sources (Table 3) and upload updated, aggregated calibration data to the ITHIM data structures and maintain the R-based web tool.	The suite of documentation includes: • Chapter 3. Programmer's Guide to California ITHIM (draft) from *User's Guide & Technical Manual* - provides an overview of the R program structure and key files for website maintenance • Appendix A. Updating the Integrated Transport and Health Impact Model (ITHIM) - instructions on processing raw data into the model's calibration parameters • Workshop for CARB staff based on Chapter 3 (above) on how to maintain the static website content (text, photos, icons, etc.)
8. Deliver a tool that will be functional through CARBs website in which the application and data are hosted on a server administered and/or managed by CARB. The UCD project teem commits to work with CARB staff to ensure that the ITHIM tool works on CARB servers, intranet and fire walls though an exchange technical and administrative information with CARB staff.	• We have provided documentation on how we implemented California ITHIM on our developmental server • We have provided documentation on how we used open source software (Electron) to create a downloadable desktop version of ITHIM
9. Provide quarterly progress reports, presentations and a final project report as well as a final seminar presented to CARB.	• We submitted quarterly progress reports. This document is the draft final report, and materials from the User Support will incorporated into a final seminar.

DISCUSSION

We reproduced the functionality of the spreadsheet version of California ITHIM as an open source, web-based software application using the R programming language and the Shiny HTML generator. The interface incorporated elements of CARB's website design standards and may be deployed on the internet or as a stand-alone desktop application. Compared to its spreadsheet analogue, the R/Shiny version of California ITHIM has several enhancements including statewide air pollution data, health impact assessment performed statewide and for specific counties (compared to just regions) , and a complete collection of built-in and user-defined scenarios that can generate health assessments between 2010 and 2050 (compared to just 2010 and 2040).

Strengths

Perhaps the biggest strength of the project was engagement of its User's Group. Representatives from a diverse group of approximately two dozen organizations provided essential feedback during the development of the application. Several strategic choices appear to have contributed to the success of the User's Group. First was its reliance on organizations that had previously used the spreadsheet version of ITHIM or its products. These users are the most influential future users and will have the biggest impact on policy. Their presence obviated the need for a time-consuming basic orientation to transportation-health issues that more experienced organizations would have perceived as an unnecessary time burden. Another choice to maximum the skill sets and knowledge inherent in the User's Group was the initial division of the User's Group into those with a technical vs. policy orientation. This better aligned project needs for specific types of feedback and time spent by the User's Group. Quarterly 90-minute teleconferences appeared to be an effective medium for cycles of prototyping, feedback, and evaluation. We maintained high participation rates with the same group of representatives at each of the four User's Group meetings. Given the challenge of scheduling for such a large group, we repeated conference calls with identical content on two dates. Preparing and sending materials ahead of calls and using technologies to screen share and include both computer (VoIP) and telephonic audio increased the ways the User's Group could participate. We also responded to user questions and observations on website format and content in individual telephone follow up. Another factor that contributed to engaged participation was the personal and organizational context. Dr. Maizlish had previously worked with many of the organizations on spreadsheet ITHIM implementations, and Drs. London and Rudolph's broad network of professionals, with whom they share trusted relationships, were avid participants in the User's Group. The sponsorship of the University of California, Davis also enhanced the appeal and credibility of the project.

The internal engagement with multiple divisions and offices within the California Air Resources Board also contributed to our meeting the project goals. The contract officer and her managers in the Research Division were accessible to project staff and facilitated introductions to other key stakeholders within CARB. Scientists in the

Research Division assisted with the development of the air pollution data and helped harmonize small differences in methodologic approaches over several meetings.

Early and ongoing involvement of the Office of Communications and the Office of Information Services also contributed to the success of the project. The Office of Communications provided essential guidance on CARB's design standards for websites. We were able to directly incorporate CARB's color palette, and Drupal templates provided a reference for our own web page designs. The Office of Communications also provided access to CARB's gallery of iStock photographs, many of which were incorporated into the final product. Also, feedback from reviewers at the Office of Communication helped us progressively align website drafts with CARB's standards. The Office of Communications also shared technical information on website accessibility which we used in our testing procedures.

Early contact with the Office of Information Services was also an essential component of the project. Their participation helped us better understand CARB's technical requirements for developing and supporting web-based and desktop downloadable software, including cybersecurity.

Lastly, our development team at UC Davis brought together diverse skill sets that included subject matter expertise (in epidemiology), graphic design, code writing (R, Shiny, HTML, CSS), system and server architecture, and community engagement.

Limitations and Challenges

We were able to meet all the technical requirements to create the deliverables for this project. For the requirement of creating tables and graphs that were downloadable as PDFs, we encountered technical challenges for the server-based version of California ITHIM (but not the desktop application). We explored the LaTex package (https://cran.r-project.org/web/packages/latexpdf/latexpdf.pdf), which is open source software and a standard for processing text and tables as PDFs. We found that this package was not fully operable on either the Apache or Ubuntu Linux operating systems. After consulting RStudio and community bulletin boards, we did not find any published solutions. We then proposed that we could meet this requirement by saving tables and graphs as a PDF through their browser.

We designed the R/Shiny application so that data files and default values of model parameters may be easily updated without any R programming and that website text, photos, and icons could be easily revised from external CSV-formatted files that combines text with a few HTML tags for hypertext links, bullets lists and a few other text elements. Our software development was guided by a programming paradigm that avoided advanced programming techniques (object-oriented programming) and R packages. This may have led to longer, less compact code. However, this does not suggest that the coding of the interface or analytic engine program was simple or can be causally changed. The application has over 8,000 lines code, and despite the several types of documentation, making changes in the code will be a significant challenge for others without similar or more advanced skills sets than those of the developers. Many lines of our R/Shiny code for the Tool page deals with the handling and formatting of graphic images (for the infographic) and the aesthetics of formatting table headers and numbers in tables so they are right justified and do not have an excessive number of decimal places, which occurs using R command defaults (renderTable).

The code underlying the R/Shiny version of California ITHIM should be stable, functional, and relevant until the next major updates of demographic, health, and travel data, which will most likely occur after the 2020 U.S. census and the next iteration of the California Household Survey, or its equivalent.

The application was designed for viewing on desktop computers. We recognize that tablets, smart phones, and other mobile computing devices are a growing share of the computing environment, but that designing the ITHIM application for these devices was beyond the scope of the project.

As of this writing, CARB's options for deployment the software are being explored. As part of the scope of work, we demonstrated the feasibility of server-based and downloadable desktop deployments. The application deployed on its developmental server (http://cal-ithim.org/ithim) is not intended to be a permanent hosted solution. We have facilitated meetings between CARB's OIS and RStudio, which offers premise-based R server solutions with Linux operating systems, as well as cloud-hosted solutions. Each of these has different levels of commitment of CARB staff resources and cybersecurity features (authentication, countermeasures to avert graffiti and bot attacks, etc.). We have also facilitated discussions with the Information Technology Services Division of the California Department of Public Health to explore whether, through a joint agreement, the California ITHIM application can be hosted on CDPH's existing R server, which meets state administrative requirements for cybersecurity.

SUMMARY AND CONCLUSIONS

Under this contract, the University of California, Davis successfully developed an open-source, web-based version of California ITHIM that is easy-to-use and provides users with a rich menu of scenarios and decision-support materials to explore the health impacts of active transport as a strategy for greenhouse gas reduction in California's transportation sector. Current and potential users at CARB, state, regional, and local government, and community-based organizations were engaged in the development of the software. With training, CARB staff will be able to maintain the website over the next 3-5 years, after which updating of calibration data will be highly desirable.

RECOMMENDATIONS

A number of recommendations emerged through discussions in the User Group and small MPOs. These include valuable insights provided by Users, but were beyond the scope of this contract.

1. We recommend the deployment of the R/Shiny California ITHIM on a platform that is readily accessible and barrier-free to users. This is most embodied in a premise-based server under CARB administration, solely or jointly with other state agencies stakeholders (e.g. CDPH, Caltrans, Strategic Growth Council, UC Davis, etc.). Limiting deployment as a downloadable desktop version will likely present significant barriers to its use by a broad array of stakeholders, whose expectations may not align with this deployment strategy.

2. Users expressed interest in research to promote more geographically resolved versions of ITHIM. Such efforts are underway at the University of Cambridge, UK, in which individual-level population simulation is coupled to individual level transportation simulation. Individuals are georeferenced across their daily travel journeys. This approach also facilitates more detailed equity analyses of population subgroups.

3. Small MPOs are potential users of California ITHIM, but face barriers in compiling their own calibration data. Representatives of MPOs expressed interest in pursuing grant opportunities to carry out these tasks and pooling resources. The scope of work in this project included counties and regions covered by spreadsheet ITHIM. Extending the geographic coverage to other regions and counties should be explored. Users expressed an interest in how the aggregate version of ITHIM might be applied to small geographies or other situations in which sparse data may be a barrier to application of ITHIM.

4. Although the California ITHIM has an easy-to-use interface, tutorials, and documentation, some users may need technical assistance in running the model, preparing uploadable (scenario) data files, modifying calibration data, or interpreting results. We recommend CARB exploring mechanisms to provide technical assistance to users.

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GLOSSARY OF TERMS, ABBREVIATIONS, AND SYMBOLS

Abbreviation	Description
ABM	Activity-Based (Travel Demand) Model
BAU	Business as Usual
BD	Burden of Disease (includes injury)
CARB	California Air Resources Board
CDPH	California Department of Public Health
CHTS	California Household Travel Survey
CHIS	California Health Interview Survey
CRA	Comparative Risk Assessment
CV	Coefficient of variation (standard deviation/mean)
CVD	Cardiovascular Disease
CSS	Cascading style sheet
DALY	Disability Adjusted Life Year = Years of Life Lost + Years Living with Disability
EMFAC	EMissionFACtorsmodel
GBD	Global Burden of Disease (includes injury)
HHD	Hypertensive heart disease
HTML	Hypertext Markup Language
ICD	International Classification of Diseases (5-digit hierarchical code)
IDE	Integrated development environment
ITHIM	Integrated Travel and Health Impact Model
MPO	Metropolitan Planning Organization
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)
R	Free, open source statistical computing language
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
shiny	An R package that generates HTML to create web pages of R outputs
SWITRS	Statewide Integrated Traffic Reporting System
UCD	University of California, Davis
VMT	Vehicle Miles Traveled
WHO	World Health Organization
YLD	Years Living with Disability
YLL	Years of Life Lost

APPENDICES

A. USER GROUP MEETINGS

USER GROUPS MEETING SUMMARIES

TECHNICAL USER GROUP SUMMARY (2018-07-25)

Recording of meeting available at:
https://global.gotomeeting.com/play/recording/TGU9rmpJPr0kLWOJDjJ6aCXpDW8HmM

Attendees

University of California, Davis, UCD (organizers)

Neil Maizlish, Project Lead; Kenji Tomari, Graduate Student Researcher; Sarah Grajdura, Graduate Student Researcher; Caroline Rodier, Institute of Transportation Studies; Alex Karner (consultant), University of Texas, Austin; Amy Weiher (consultant), Web Designer

Air Resources Board

Cynthia Garcia, Contract Manager; Jason Rucker, Office of Information Services

Users Group:

10 representatives from MPOs (MTC, Fresno COG, SACOG, SCAG), state agencies (CalTrans, CDPH), Local health departments (Los Angeles County Department of Public Health), and air quality management districts (SMAQMD)

Introduction

This project is funded by the California Air Resources Board (CARB), and we (UCD) plan to have the web application up and running by May 2019. The web "app" will recreate the functionality of the existing spread sheet version of ITHIM as an open source R program, accessible online with a user-friendly interface. The website will be maintained by CARB.

Summary of Discussion

Regional Downscaling

ITHIM California is part of a larger family of ITHIM projects being developed in the United States and England. Researchers like Alex Karner (University of Texas) are currently working on individual level travel simulations of entire populations that can be later aggregated at different geographic scales. Individual simulation is beyond the scope of our ITHIM Update project. However, we are interested in knowing what users would like in future versions of ITHIM.

The existing spreadsheet version of ITHIM downscales regional results taking into account the age and sex distribution of the sub-regional target population. A user asked whether small area estimation (SAE) methods could be added to the model. We are aware of one such approach using place types based on the work of Debra Salon at Arizona State University (Salon D. Estimating pedestrian and cyclist activity at the neighborhood scale. *J Transport Geogr* 2016; 55: 11–21). She demonstrated a technique for estimating walking and cycling behaviors within generalized strata of urban-suburban-rural geographies and applying this knowledge to small areas whose mix of urban-suburban-rural geographies may vary.

Use of MPO Models & Improvements to ITHIM

In response to a user question regarding sources of data, we source motorized modes from MPO travel demand models and active modes (walking and cycling) from the California Household Travel Survey, 2012. We noted that each MPOs has a different way of characterizing travel modes. In response to a question regarding the volume of motorized vehicles, we use outputs from MPOs' travel demand models which has the number of vehicles traveling on segments of known length in the road network of their jurisdiction. Because the injury module in ITHIM uses roadway type (highway, arterial, local road), as a surrogate for traffic volume and speed, MPOs data on roadway type and vehicle miles traveled (VMT) is incorporated into ITHIM's calibration.

An MPO representative proposed UCD consider an additional feature to ITHIM as a useful policy tool. He suggested that the web app allow users to interactively vary the percentage of bicycle (or pedestrian) travel between local roads and arterials, which have inherently different injury risks based on speed and volume, as well as the total amount of cycling. This feature, coupled with knowledge or predictions of how safety infrastructure (e.g. protected bicycle lanes) alter injury rates, would be particularly useful. This suggests that the effect size of different safety measures be included as website decision support materials.

A CDPH user suggested that it would be useful to include scenarios that capture health improvements from changes to safety associated with changing travel onto different roadway types. Additionally, he recommended a new scenario without any transport-related physical activity. UCD noted that this is already possible in ITHIM using the What-If Calculator, but few users are aware of how to generate this scenario.

Decision Support

UCD intends to provide decision support information to users on the ITHIM web app. Some potential materials include links to meta-analyses of physical activity and health outcomes, summaries of these meta-analyses, types of interventions to enhance active travel and its safety, and the effect size of different interventions. The representative from Los Angeles County Department of Public Health (LACDPH) suggested that decision support around land use strategies would be helpful. To collect potential information, it was suggested by a LACDPH representative to create a discussion group supported by a Wiki.

Formatting Data

The UCD team recognizes the need for standardized formats that MPOs and others can use to upload their own scenarios. The user from MTC underscored the importance of documentation in this process. A CDPH user suggested a programming technique to create an R object that might aid in determining missing parameters, identifying data corruption issues, and improving portability. The UCD team said it will explore a system of edit checks for uploaded data, with at least two levels: 1) an error message for fatal errors and 2) warning messages for data that may be unreasonable. The MTC representative also asked if the R application source code will be available for users to run the model locally rather than as a web application. The UCD intends to make the R/Shiny source code available for users who could run the model locally (not connected to the web).

Input

The data uploaded to the ITHIM web application will be temporary and be deleted after each web session. Data inputs are aggregate, and do not include any personal information, which would raise potential security issues. The MTC representative expressed the need to log configuration data (i.e. “breadcrumbs”) in order to ensure reproducibility of specific ITHIM runs. The UCD team acknowledged the need to create a downloadable, user configuration file that users could upload again when there was a desire to retain certain settings through different model runs.

Output

The LACDPH representative expressed a need to present results for different subgroups such as socioeconomic status. The UCD Team noted the difficulty of creating subgroup analyses based on variables such as race/ethnicity because empirical data from travel surveys have many sparse cells (after breaking the population of active travelers by age, and gender). The UCD team said it would look into possible solutions because equity analyses are important to users. In addition, a CDPH user requested the UCD team look into creating a mini-report with some contextual information as a new output for ITHIM.

Follow-up Items for UCD Team

- Explore possible use of small area estimation techniques
- Create a discussion group or other mechanism for compiling/curating decision support materials on policy, system, and environmental changes to increasing safe active transport and its health impacts
- Research R objects that might aid in determining missing parameters
- Design a user configuration figure to retain model settings for different ITHIM runs
- Explore solutions to subgroup/equity analyses in which sparse cells may be a severely limiting factor.
- Explore a mini-report output format

POLICY USER GROUP SUMMARY (2018-07-30)

Meeting recording available at:
https://global.gotomeeting.com/play/recording/pELOcpP8ZXt0nCy4o3cO1FOIznaHxZ

Attendees

University of California, Davis, UCD (organizers)

Neil Maizlish, Project Lead; Kenji Tomari, Graduate Student Researcher; Sarah Grajdura, Graduate Student Researcher; Linda Rudolph, Center for Climate Change and Health; Amy Weiher (consultant), Web Designer

Air Resources Board

Cynthia Garcia, Contract Manager; Jason Rucker, Office of Information Services

Users Group:

15 representatives from MPOs (SANDAG, San Joaquin COG), state agencies (CalTrans, CDPH, Strategic Growth Council), local health departments (Public Health Alliance of Southern California), and 7 non-governmental organizations representing local elected officials, climate education, environmental justice, health, and active transportation.

Introduction

Linda Rudolph at the Center for Climate Change & Health provided a short introduction citing ITHIM as a good example projects that integrate health and equity considerations into the development of climate, transportation, and land use policy. It can have a huge impact on the health of communities, and democratizing the availability of tools to look at health strategies and scenarios.

This project is funded by the California Air Resources Board (CARB), and we (UCD) plan to have the web application up and running by May 2019. The intended design of this web app will be to recreate the existing functionality of the ITHIM spreadsheet program into an open source R program accessible online, with a more user-friendly interface. It will be maintained by CARB.

Much of our active transportation information comes from the California Household Travel Survey (CHTS). The most recent version of spreadsheet ITHIM includes recent scenarios of major MPOs for SB375, the CalTrans Strategic Management Plan 2020, the ARB 2030 scoping plan, and recommendations of the US Surgeon General. The ITHIM model also has a “What-if” calculator that allows users to add multiples of baseline levels of active transportation, and specify absolute amounts of daily walking and cycling time. The outputs of ITHIM include annual number of deaths, disability adjusted life years (DALYs), population attributable fractions (PAFs), and greenhouse gas emissions from cars.

Summary of Discussion

Incorporating New Findings

The CDPH user mentioned that new evidence indicates a link between air pollution and diabetes and whether the update will include changes to reflect this new evidence. In response our (UCD) aim is to first make the existing ITHIM model part of an operational open source website. If we're able to complete this task with spare time, then we may be able to include new exposure-disease pathways (such as fine particulate pollution and diabetes, or physical activity and lung cancer) and update the existing exposure-disease pathways. This focus of taking existing functionality into the web application is also true for other areas of concern. For instance, although on many peoples' minds these days, the independent contributions from increased wildfires is not in our scope. Nonetheless, we are interested in your recommendations for new exposures and health pathways for future versions of ITHIM. So, please contact Neil with any queries about including more recent data that you have.

Downscaling

Downscaling in the existing ITHIM is based on applying regional estimates to smaller geographies, taking into account the age and gender composition of the target population. This makes a strong assumption that the travel patterns at the region hold for smaller geographies. When downscaling from CHTS, we often find very sparse data for active transport in different subgroups, such as biking at older ages. As an alternative, some researchers are starting to use sophisticated modeling techniques to simulate each individuals' travel behavior and then sum up over the entire simulated population. This approach is outside the scope of this project. However, we will be working with users to determine the pros and cons of adapting the existing ITHIM downscaling technique to the web version.

CARB Scoping Plan

The CDPH user asked whether the CalTrans Strategic Management Plan scenario (doubling walking and transit and tripling cycling from the 2010 baseline by 2020) generates essentially the same health benefits as the ARB Scoping plan scenario, which quadruples walking and transit and increases cycling 9-fold from the 2010 baseline by 2030. Although the CARB Scoping Plan appears to be a ten year extension of the Caltrans Strategic Management Plan, it does generate a greater absolute amount of health benefits and has a greater per year increase compared to the CSMP.

Capturing Improvements in Active Transportation

A user asked whether ITHIM can capture MPO investments in active transportation and its impacts. This is akin to asking "what magnitude of investment would be needed to move the needle on active transportation?" The model itself does not directly do this type of calculation, and it depends on how the scenario is defined. The model predicts changes in health benefits based on changes in travel behaviors, but the link between changing travel behaviors and infrastructure (or other investments) is what informs the scenario. However, we (UCD) plan on providing literature and evidence for possible effect size for different types of investments or interventions through decision support materials. We would like user input on this.

ITHIM as a Means to Educate Policy Makers

A NGO user suggested that data generated by ITHIM could be utilized like a study, which could be cited as a proof of benefits for active transportation; to use it in working with communities on Active Transportation Plan (ATP) applications and summarize health effects of existing conditions versus improved conditions in local plans. The biggest challenge with ITHIM is providing user-oriented data. Another NGO user commented that ITHIM outputs on a sub-MPO level would be useful for county level agencies.

Various Technical Concerns

In early versions of ITHIM in California, the model and outputs were tied to a base year (~2012). However, the existing spreadsheet version has been improved and can project travel and health outcomes into the future. So, in addition to a baseline, we can project Business-As-Usual (BAU) scenarios as the reference for comparison with other scenarios. We plan to add information on age, gender, and population counts for California counties through 2050.

Output for Grant Writing (i.e. Greenhouse Gas Reduction Fund grants)

The output of ITHIM could help support large regional projects. It would not be appropriate for census level tract, but downscaling (mentioned above) may be suitable for municipal or greater area analyses. We (UCD) will provide documentation, possibly in the format of videos, to support to users who may want to use ITHIM output for grant programs.

Communicating Findings with Regional Partners

We would like to make the output of ITHIM as transparent as possible. We could make the output more accessible by providing additional support material that community-based organizations can cut and paste, such as mini-reports. We want to work with users to create more accessible formats.

ITHIM and Modeling Injuries

A user asked how ITHIM takes into account safety infrastructure for active transport. The ITHIM model does a calculation based on the scenario, which takes into account changes in travel behavior (i.e. increased mode share for walking or cycling) and its safety (i.e. decreased injury risk). Decision support is a missing link which would provide a summary of the evidence for different types of infrastructure and their effects. We welcome users to contact us to recommend key literature that addresses this so we can make it available on the website.

Communicating the Limitations of ITHIM

An NGO user recommended that it is essential to be clear about what the model is and is not able to do. We can address this by stating the caveats and having robust documentation. For example, the ITHIM model's focus on chronic disease doesn't provide much data on youth health impacts. One response is to provide information in a decision support section of the website about the links between youth and adult physical activity, childhood obesity, and their health impacts later in life.

Format of Web App

We're planning to have the ITHIM web app follow a standard format (see slides). It includes a navigation bar at the top of the window with a number of links, such as decision support, scenarios, outcomes, and documentation. An MPO user suggested that the webpages utilize graphics and visuals, especially in the first couple of pages to help people put information together.

Follow-up Items for UCD Team

- Check-in with the ITHIM research team at the University of Cambridge for the status of their review of the scientific literature and their recommendations for updating ITHIM exposure-disease relationships for existing and new exposures and diseases.

- As previously recognized by Technical users, create a discussion group or other mechanism for compiling/curating decision support materials on policy, system, and environmental changes to increasing safe active transport and its health impacts

- Ensure that there is website content that clearly states what the model does, its limitations, and assumptions.

- Explore a mini-report output format and other accessible formats for outputs

USER GROUP WEB DESIGN CONFERENCE CALL SUMMARY

Recordings of meetings are available at:

10/24/2018: https://drive.google.com/open?id=12ePrqPtB1gbvBGWbVnW8z19Lbi4dm3D3

10/29/2018: https://global.gotomeeting.com/play/recording/122c3b3860e9ac9b0b7d8631e52135980a0245521ba5b9b94bd5c59295db5ec7

Attendees

University of California, Davis, UCD (organizers)

Neil Maizlish, Project Lead; Kenji Tomari, Graduate Student Researcher; Sarah Grajdura, Graduate Student Researcher; Caroline Rodier, Institute of Transportation Studies; Amy Weiher (consultant), Web Designer; Jonathan London, Co-PI, UC Davis, Linda Rudolph (consultant); Chengsheng Jiang (consultant)

Air Resources Board

Cynthia Garcia, Contract Manager; Maggie Witt, Air Pollution Specialist, Research Division

Users Group:

24 representatives from 17 organizations representing MPOs (MTC, Fresno COG, SCAG, SANDAG), state agencies (Caltrans, CDPH, SGC), local health departments (San Francisco, Los Angeles and Sacramento counties), air quality management districts (SMAQMD), and non-governmental organizations (California Walks, Safe Routes to School, Public Health Alliance of Southern California, California Lung Association, CalCOG).

Introduction

The purpose of the conference calls was to get feedback on the initial proposed design of the website application with a focus on the Home, Tool, and About pages. This feedback is a prelude to the actual coding of the website. Initial designs were provided as pdfs and example tables and graphs were presented in a chart book. The chart book also provided users with options for selecting scenarios, geographic regions and counties, and time periods for evaluation of health outcomes, costs, and carbon emissions. As prefacing remarks, Dr. Maizlish introduced guidance from the Air Resources Board on website design which included content and format such as font size, color palette, page templates that emphasize photo imagery and design of graphs and tables.

Summary of Discussion

Home Page

Users suggested improvements in the ITHIM wordmark logo, including larger font size for the spelled out name, plain font face instead of italics for the ITHIM acronym, and making the spelled out "Integrated Transport and Health Impacts Model" standardized (using US rather than British English). The banner photo generated a positive reaction as did the tagline superimposed on the photo and the following text blocks that provided framing. It was recommended that the framing make clear that the tool is geared to California, and perhaps a map of the geographies covered by the tool be introduced on the Home page.

The three large action buttons for learning about the model, learning about how to use the tool, and direct access to the tool was positively received. There was a question whether the website would be a single page or multi-pages (answer: multi-page). The general reaction to gallery of findings was positive. Questions were raised whether it should be its own page, whether the images would be legible (too small to read), whether pie charts would be better represented as doughnut charts, whether it would be obvious that clicking on the images would take the user to the document from which it was excerpted.

Tool Page

The basic visual layout was reviewed, displaying a vertical left side options panel covering 1/3 page width and vertical right side output panel covering 2/3 page width. The options panel provides users with picklists to choose a desired scenario, geographic area of interest, and the year for which the scenario is planned (between 2010 and 2050) and for which health outcomes and costs, and car-carbon emissions are projected. An array of radio buttons provided options to allow users to determine the level of detail (summary, medium, very detailed) and type of output format (narrative, infographic, graphs, tables, pdf, or text data file (CSV). Given the potentially voluminous nature of the ITHIM output, a design was suggested by parsing the roughly 18 key tables and graphs into groups of 6 by level of detail. Several users reacted positively to this proposal to display output (compared to single long vertical scroll of all output).

A question was raised regarding the year of evaluation (e.g. RTP update in 2016). Except for 2010 (which is a single year estimate), the year options are 5-year annual averages (2015-2019, 2020-2024 . . . 2050-2054) based on population projections from the California Department of Finance. Users should pick the 5 year period in which their update falls. Single year projections are possible, but the UCD team is concerned that large amounts of data loaded into the application may make it unwieldly.

Suggestions were made to improve the elevator speech, including renaming it "elevator pitch", which internet search engines apparently return at greater frequency than "elevator speech", incorporating icons or other imagery, using headings, and adding a brief narrative that summarizes the health impacts of the chosen scenario. Users gave positive feedback regarding an infographic, whose conceptual design was described as telling a story of how the transportation system provides benefits and harms that impact health, and how ITHIM directly address those related to air pollution, physical activity, and traffic injuries.

As to formats of tables and charts, users suggested the UCD team consider matching the orientation of bar charts with the contents, and that charts with numerous categories (e.g. 8 travel modes) be presented as horizontal rather than vertical bar charts. Several suggestions were made regarding numeric labels above bar charts. Some users were concerned that tool tips (revealing labels only while hovering over the bar) would be lost when copying-and-pasting the image from the website to other documents, or saving as a pdf. This discussion also generated a recommendation that UCD team consider "affordance" in the website design, when possible. This refers to appealing to user intuition on how a web element should be used (based on analogizing real world experience to the web). It was suggested to incorporate stronger visual cues (icons, map images, vs. text) in the titles of tables/graphs to indicate which scenarios and geographies were chosen to generate output.

Users were asked their preference in describing key health and cost outcomes as negative numbers or bars below 0 (indicating a lowering of the number of deaths or burden of disease) vs. positive numbers (indicating number of deaths averted or avoided). Several users suggested a positive orientation may be easier to understand, but wanted to see examples of both approaches.

About Page

The proposed format of About pages was presented (title, banner photo, brief introductory paragraphs set off by icons/images and ending in links to more detailed information (e.g., pdf opening is a new window).

User Data Uploading

The proposed approach for users to upload of their own baseline/business-as-usual (BAU) and scenario data follows the functionality of the spreadsheet version of ITHIM. This allows users to consolidate multiple scenarios (often scores) in a single CSV file, and interactively select pairs from a menu of baseline/BAU vs. alternative for each analysis. Existing interfaces between travel demand models and ITHIM created by several MPOs (MTC, FresnoCOG, SACOG, SANDAG) could be used for the R version. A separate conference call was suggested to examine the details for standardized input formats, capturing breadcrumbs, looping through large numbers of scenarios, directing voluminous output to CSV files rather than the output viewing panel.

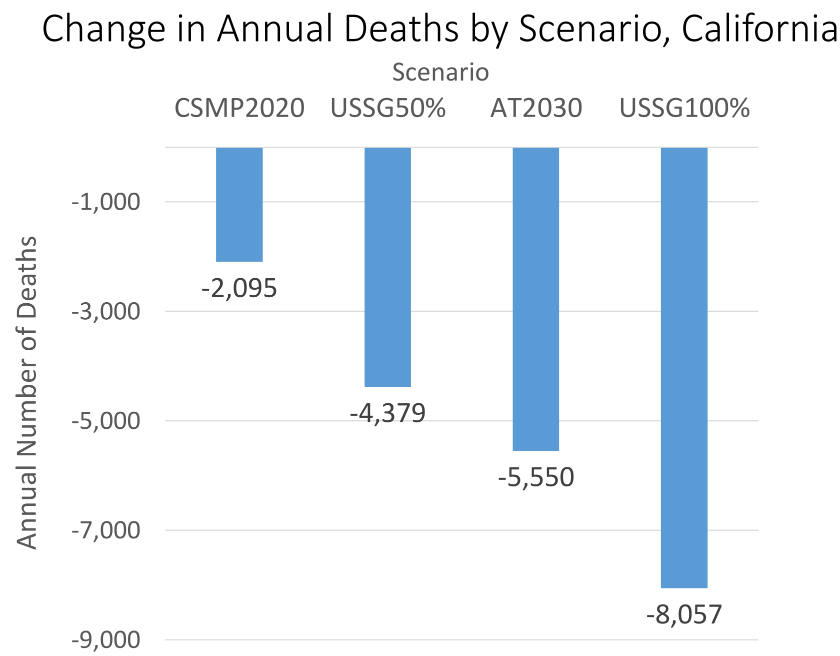
Next Steps

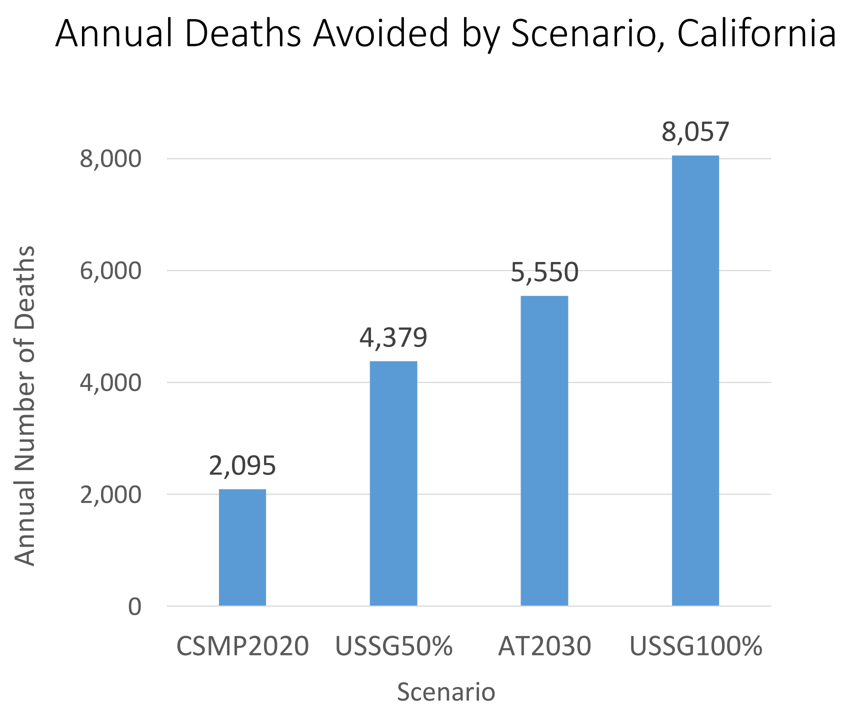
The UCD team will review the feedback and create an "alpha" version of a website that considers the recommendations and preference of ARB staff and the Users Group. The aim is to create a draft working facsimile of a website within the next two months (Nov. Dec 2018). This will allow users to explore the content and format and provide additional feedback before the User Group is reconvened in early 2019.

Follow-up Items for UCD Team

- Incorporate feedback in design of Home, Tool, and About Pages (above)
- Follow-up with representatives of MTC on specifications of user uploaded data
- Provide examples of bar charts of health outcomes using negative and positive axes (see next Page)

Two Graphs with Same Information Presented Using Negative and Positive Axes





CSMP2020, Caltrans Strategic Management Plan 2015-2020 (doubling walking and transit, tripling cycling from 2010 baseline by 2020)
USSG, US. Surgeon General, weekly physical activity recommendations for adults 50% (75 min), or 100% (150 min)
AT2030, CARB active transport goals in the 2017 Scoping Plan Update, for 2030; quadrupling walking and transit, and 9-fol increase in cycling from 2010 baseline by 2030

SUMMARY OF ITHIM USER GROUP CONFERENCE CALL, FEBRUARY 5, 2019
REVIEW OF "ALPHA" DEVELOPMENTAL WEBSITE

Recordings of the meeting are available at:

https://global.gotomeeting.com/play/recording/b1f000143c690d11bdbed08b23c39b2997 1090cb20e1a7d6d9b41f390db63539

Attendees

University of California, Davis, UCD (organizers)

Neil Maizlish, Project Lead; Kenji Tomari, Graduate Student Researcher; Amy Weiher (consultant), Web Designer; Linda Rudolph (consultant); Chengsheng Jiang (consultant), Kelley Rodgers (guest), StreetSmart.org

Air Resources Board

Cynthia Garcia, Contract Manager

Users Group:

19 representatives from 14 organizations representing MPOs (MTC, Fresno COG, SCAG, SANDAG), state agencies (Caltrans, CDPH), local health departments (San Francisco, and Los Angeles counties), air quality management districts (SMAQMD), and non-governmental organizations (California Walks, Public Health Alliance of Southern California, California Lung Association, CalCOG, Local Government Commission).

Introduction

The purpose of the conference call was to present the alpha version of the California ITHIM website (https://cal-ithim.org/ithim) to the Users Group. The development team requested feedback regarding the overall user experience, reviewed each page (Home, About, and the ITHIM Tool). The Tool page provided drafts of the Elevator Pitch, Infographic, and tables/graphs at summary, medium, and high levels of detail. Format of the options and output panels on the Tool page received specific attention. The development team also proposed content and wire frames for the Decision Support and User Support pages, whose development is just initiating.

Summary of Discussion/Participant Suggestions

Home Page

- General appearance appeared to be good. Only one participant (using Internet Explorer 11) reported a major difficulty viewing the page (for which we initiated individual follow-up to determine the possible cause.)
- A favicon and website name should be added to the title tab.
- As browsers were resized there was some content shifting of the banner text overlay.
- At 100% browser sizing, the following items have large font sizes and many words per line (giving a very wide field of view)
    - banner message and banner caption
    - action buttons
    - introductory text of the image gallery
- The gallery images should be hypertext linked rather than just the figure captions.
- The horizontal scroll bar at the base of the browser is unnecessary.

<u>About Pages</u>

Our team had concern over the quantity of information present on the About pages—particularly as it regards navigation.

- General: Participants suggested placing a left-side panel menu to navigate between About pages vs. creating a single very long About page, perhaps using collapsible text boxes (accordions) to reduce length.

- Introduction: participants found the language appropriate for professionals that may not be well-versed in the material. Further it provided a good grounding for the basics.

- Instructions: Participants found the text to be lengthy and suggested that Scenarios, Geographies, and Time Periods be presented in (their own) three column format.

- Scenarios: It was recommended that headings be added to distinguish between agency or goal-based scenarios (CARB2030, CSMP2020, SCS2040, US Surgeon General) and "What If" scenarios (multiple of baseline, fixed time, short trips, low carbon driving). Also, additional language is needed to clarify that unless a user uploads their own data, the comparison data are derived from the 2010 baseline.

- Geographies: The two column county list was confusing, perhaps better presented as a single column table.

<u>Tool Page</u>

- Infographic: participants were pleased with the aesthetics. A concern was raised that some users may be unfamiliar with terms like "DALYs", which may deserve a tool tip or other explanatory aid or glossary. Units in billions of dollars for the costs were hard to understand as decimal values (<0.1). Perhaps a shift from billions to millions would make the figures more understandable.

- The UCD team presented several possible modifications to the layout of the options panel and scrolling of the results (elevator pitch, infographic, tables, and graphs). There were no strong preferences as to whether the options should all be consolidated above the output panel or to the left of the results panel.

- Download of tables/graphs: participants preferred having multiple tables downloaded in a single file (i.e. a csv" Excel-like) rather than individual tables in a zipped file.

- What if Multiples of Baseline: sliders and scale are off. (Need to reconcile multiples expressed as an integer vs. percent.)

<u>Decision Support</u>

- Dr. Maizlish acknowledged Kelly Rodger's assistance in developing the ideas for the organization of Decision Support materials
- The UCD team proposed major content areas as 4 subpages: Health Outcomes, Strategies, Evidence, and Data & Resources. The content responds to user needs to put the health co-benefits in the broader public health context for California (especially chronic disease and equity) and provide more information on the policies, projects, and other interventions that can help achieve the main strategies of increasing physical activity, improving roadway safety, and decreasing air pollution, greenhouse gases, and vehicle miles traveled.
- A basic two panel wireframe was presented that allows users to select a strategy (left side panel navigation menu) and view in a right main panel a narrative of possible actions associated with the strategy.
- Equity was also introduced as a significant cross cutting theme, and participants' experiences and materials on this topic were requested by the UCD team.
- In general, participants seemed to be comfortable with the proposed approach to decision support materials.

<u>User Support</u>

- The UCD team presented the following items as the core of user support materials: short video clips on navigation the website, a 1-2 page "cheat sheet for website navigation, data upload instructions for more advanced users, a chart book of ITHIM tables/graphs for several scenarios by region, ITHIM educational workshop slides, a user manual, and a technical manual.
- In general, participants seemed to be comfortable with the proposed approach to decision support.

Next Steps

The UCD team will review the feedback and create a "beta" version of the website that considers the recommendations and preference of ARB staff and the Users Group. This will allow users to explore the content and format and provide additional feedback before the User Group is reconvened in Spring 2019.

Follow-up Items for UCD Team

- Incorporate feedback in fine tuning of the Home, Tool, About Pages, and in the design and build out of Decision Support and User Support pages

- Individual follow-up of a few participants to determine why the developmental website did not view properly in their browser.

2/12//2019

SUMMARY OF ITHIM USER GROUP CONFERENCE CALLS, MARCH 25 & 27, 2019
REVIEW OF "BETA" DEVELOPMENTAL WEBSITE

Recordings of the meeting are available at:

March 27:
https://global.gotomeeting.com/play/recording/d8ef9aac18564a31ca4000a3cbeb469c1fe92459ca7eab7994774cde40e2ca92

March 25:
https://global.gotomeeting.com/play/recording/967154300ecd987cb888cc8969e2e09ffbae8acab8a8835e645370543def78ea

Attendees

University of California, Davis, UCD (organizers)

Neil Maizlish, Project Lead; Kenji Tomari, Graduate Student Researcher; Amy Weiher (consultant), Web Designer; Linda Rudolph (consultant); Dana Rowangould (consultant); Kelley Rodgers (guest), StreetSmart.org

Air Resources Board

Cynthia Garcia, Contract Manager

Users Group:

15 representatives from 12 organizations representing MPOs (Fresno COG, SCAG, SANDAG), state agencies (Caltrans, CDPH, SGC), air quality management districts (BAAQMD, SMAQMD), and non-governmental organizations (Safe Routes to School, Public Health Alliance of Southern California, Local Government Commission, California Environmental Justice Alliance).

Introduction

The purpose of the conference call was to present the beta version of the California ITHIM website (https://cal-ithim.org/ithim) to the Users Group. The beta version had much of the functionality available for each web page. The development team requested feedback regarding the overall user experience and reviewed each page. Format of the options and output panels on the Tool page received specific attention, as did the content and format of the Decision Support and User Support pages.

Summary of Discussion/Participant Suggestions

Home Page

- The recommendations from the February 5 User Group conference call were implemented in the beta version (font sizes more distinct for header, subheader, and text levels; favicon added in title tab; reading line width narrowed; superfluous horizontal scroll bar removed; entire gallery images hyperlinked.)

- Several comments that the page looked great.

About Pages

- The recommendations from the February 5 User Group conference call were implemented in the beta version (Three column format for Instructions, county table in Geographies single column format and language making explicit which counties had available data)

- Introduction > How ITHIM Has Been Used? A question ITHIM's use in CARB's 2017 Scoping Plan Update not explicitly mentioned in the Introduction. Dr. Maizlish mentioned that it is included in the general category of agency plans, and is highlighted in the Scenarios.

Tool Page

Due to some technical challenges and late arrival of air pollution data, not all of the functionality of the Tool Page was available in the March 20, 2019 beta version.

- Several comments to the effect that the general functionality seems good or "cool."

Elevator Pitch

- There was a request to consider color coding the numbers in the Elevator pitch to indicate better or worse outcomes. Dr. Maizlish replied that while visually attractive, using color alone to make a point, is not accessible to some with visual impairments.

- A User made the recommendation to add the clause ‘Without safety improvements" in the statement regarding ITHIM prediction of increased fatal injuries to pedestrians and cyclists. [Note by development team: Because it is possible that some scenarios will reduce pedestrian and cyclist fatalities, this line of the elevator pitch has to accommodate the full range of scenarios.]

Infographic

- Specific comments liking the infographic, and consideration of an additional comparison that would merge the health benefits of the US Surgeon General with the air pollution, carbon, and VMT reductions of the Low Carbon Driving Scenario. Dr, Maizlish said this was out of scope for current project, but was possible. It would allow for the possibility of less overall travel. The current comparison scenarios have same overall mobility as the 2010 baseline.

- A question was raised as to the target audiences of the elevated pitch and infographic. The primary distinction between the two is that the Infographic provides comparisons with other scenarios and the Elevator pitch only compared the chosen scenario with its baseline. The Infographic may have greater appeal to policy-oriented analysts who would like to better understand which scenarios offer the greatest health cobenefits by health pathway (air pollution, physical activity of active travel).

- There was a suggestion that because the Infographic has lay appeal that technical terms (DALYs be spelled out and/or explained in simpler terms.

- Users said that right clicking on the Infographic image (rather than having a special button) would be adequate to download and save the image (as a .png or other image type).

- Users raised a question about the feasibility of printing out the image and its resolution (currently at 150 dots/inch). The development team said they would experiment with higher resolution and an alternative to the .png format.

- As to the content of the Infographic, users recommended that the framing include a statement regarding the predominance of chronic disease in driving the burden of disease in California and the importance of physical activity in chronic disease reduction. (It was pointed out that such statements appear in the About Pages and The Decision Support > Health Outcomes.

- Users indicated a preference for table formats with fixed width rather than full screen width, which exaggerates the amount of white space between table columns in the Summary level tables, and deferred to the development team regarding specifics.

- User Upload data: it appears that the data template and approach for uploading data will meet the needs of smaller MPOs who typically do not have more than a few scenarios to run in their RTP updates. Connecting the analytic engine of R/Shiny ITHIM directly to travel demand models (bypassing the R/Shiny interface) may be a more suitable option for MPOs with scores of scenarios. This approach is being taken by MTC, who have been willing to share their experience with other MPOs.

<u>Decision Support</u>

- Dr. Maizlish acknowledged Kelly Rodger's assistance in developing the ideas for the organization of Decision Support materials

- The term "Decision-Support" was not intuitive for some users who suggested the development team look into alternatives (such as Implementation)

- There were several comments to the effect that while there was much content to absorb, the content was useful, including the health outcome information.

- Several Users said that they were still reviewing the content and would send in suggested revisions and additional resources.

- The Development Team was asked to consider referring to pedestrians and cyclists as "people walking and biking", with whom readers may identify. The development teams said that follow-up with the CARB Office of Communications may be useful.

- In general, participants seemed to be comfortable with the proposed approach to decision support materials.

User Support

- The UCD team presented placeholders for user support materials: short video clips on navigation the website, a 1-2 page "cheat sheet for website navigation, data upload instructions for more advanced users, a chart book of ITHIM tables/graphs for several scenarios by region, ITHIM educational workshop slides, a user manual, and a technical manual.
- In general, participants liked the look-and-feel of the User Support Page.

Next Steps

The UCD team will review the feedback and revise the "beta" version of the website that considers the recommendations and preference of ARB staff and the Users Group. The development team will add functionality and User Support page content in April and May 2019. Users will be notified when the beta test site (https://cal-ithim.org/ithim) is updated so they can provide additional feedback. It is anticipated that the project will undergo scientific review by CARB in the summer of 2019 and CARB will decide on the methods of application dissemination by the fall of 2019.

* * * THANK YOU * * *

All the User Group participants are gratefully acknowledged for their time, expertise, and contributions to improve California ITHIM and make it useful for a broad range of users.

4/2/2019

B. CHART BOOK OF PROTOTYPES OF TABLES AND GRAPHS

(See https://cal-ithim.org/ithim/ITHIM_chartbook_california.pdf)

C. CALIFORNIA ITHIM USER'S GUIDE AND TECHNICAL MANUAL

(See https://cal-ithim.org/ithim/ITHIM_manual.pdf)