**Summary Report:**

# California Public Health Assessment Model (C-PHAM):

## Methods, Data & UrbanFootprint Application

Prepared for:

- Technical Advisory Committee
- Strategic Growth Council & Office of Policy Research
- Sacramento Area Council of Governments
- Southern California Association of Governments

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Date: July 10, 2015

URBAN DESIGN 4 HEALTH

CALTHORPE ANALYTICS

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# Acknowledgements

Urban Design 4 Health (UD4H) and Calthorpe Analytics would like to thank the California Strategic Growth Council, Resources Legacy Fund, Sacramento Area Council of Governments, and Southern California Association of Governments for their funding, support, and leadership in this effort. We would also like to thank the many individuals who contributed their time and effort generously via the project's Steering and Technical Advisory Committees.

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## Introduction

This project advances the ability to directly assess and predict how built environment (transport and land use) strategies will impact public health in California. It draws upon an unprecedented wealth of built environment, travel, and health outcome data and integrates it into an innovative new scenario-planning platform with access to powerful cloud computing capabilities. The result is an enhanced ability to both understand and apply evidence on the connection between built environment factors, physical activity, and related public health outcomes.

The project team consists of Urban Design 4 Health (UD4H) and Calthorpe Analytics. UD4H developed the public health models based on comprehensive analysis of health and travel behavior data spatially linked with built environment data. Calthorpe Analytics created the built environment data canvas to support model development. Once the models were built, UD4H validated results against external data sources. Results were then reviewed by the project Technical Advisory Committee (TAC). Finally, Calthorpe Analytics led the effort to integrate the public health models into the UrbanFootprint (UF) framework and pilot test them.

UF, developed by Calthorpe Analytics, has been supported by California state and regional agencies for the purpose of evaluating the impacts of land use plans, transportation impacts, and other critical policies in the context of climate change planning requirements pursuant to Senate Bill (SB) 375. UF is currently being used by select California Metropolitan Planning Organizations (MPOs), including the Sacramento Area Council of Governments (SACOG) and the Southern California Association of Governments (SCAG), to inform long-range planning processes. These and other California MPOs have expressed an interest in incorporating health impacts into their planning practices and/or including health metrics during the current round of Regional Transportation Plan / Sustainable Communities Strategy (RTP/SCS) updates, pursuant to SB-375 requirements. The California Public Health Assessment Model supports the integration of health into RTP/SCS processes.

This report serves as a summary document of the development and pilot application of the California Public Health Assessment Model. It presents the results of its deployment in two pilot study areas – Orange County (SCAG) and Sacramento County (SACOG). First, a brief history is presented of the interest in health modeling within the context of scenario planning. Next the three main data sources are described including exploratory analyses required transformation of each:

- an augmented UF Built Environment database (including demographic covariates);
- the California Health Interview Survey (CHIS); and
- the California Household Travel Survey (CHTS).

These datasets were joined together, resulting in models to predict physical activity, BMI, and health outcomes such as diabetes, cardiovascular disease, and general self-reported well-being. Models were also stratified by age (child, youth, adult, and seniors) and three-income levels for adults. The model development is detailed, followed by a summary of five different validation exercises.

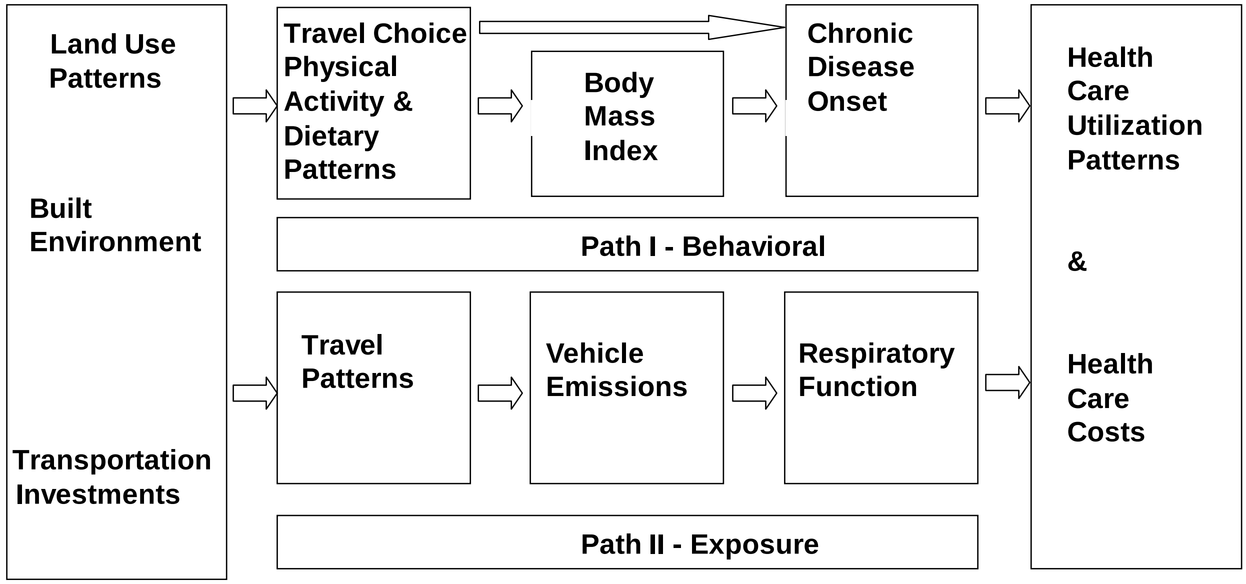
The models developed provide locally-derived relationships between the built environment and health related outcomes. The large sample size and considerable variation in built environments and demographics underlying the models allow for application of the module to regions within California and potentially across the nation. The final section of this report details two pilot case studies to illustrate how the Public Health Module results can be presented and interpreted to enhance scenario planning.

## Background

A primary goal of the Public Health Assessment Model is to use California data to predict relative health impacts associated with contrasting proposed changes in land use and transportation investments. This work is an update to an already developed set of health metrics that were developed by UD4H and integrated into version 1.0 of UrbanFootprint. This work was conducted in 2012 as part of the Vision California project. This work has now been expanded and operationalized using California-specific data. This was done while UrbanFootprint was being updated to strengthen and expand its capabilities as a web-based scenario development and analysis platform.

Interest in including health in RTP/SCS processes reflects a growing understanding of the relationships between built environment characteristics and health outcomes (including physical activity, obesity, and respiratory health) over the past two decades.[1–4] While most of this work has been cross-sectional, more recently there have been studies suggesting that this connection is likely causal in nature.[5–8] Some research has extended the links between land use and transportation characteristics (built environment), behavior, and body weight to a range of morbidities including cardiovascular disease,[9–12] cancer,[13–15] and diabetes.[16–18] Other studies have made clear connections between transportation-related air pollution exposure and a range of health impacts.[19–21] The nature of these linkages between built environment features and health outcomes is conveyed in Figure 1 below and constitutes a "causal pathway."

**Figure 1. Conceptual model of transportation and land use impacts on health and costs.**




The conceptual model shown in Figure 1 conveys behavioral and exposure based pathways that link the built environment with health outcomes and related costs. It is an over-simplification of many complex relationships. For example, some relationships are bi-directional and flow in both directions; for example body mass index (BMI) likely impacts physical activity levels. Each arrow represents a body of evidence being developed to connect these elements along what appears to be a causal pathway. All of this work feeds into one of the first evidence based quantitative health impact assessment models. Building health outcomes directly into decision support tools like Urban Footprint that are already being used to inform land use and transportation decision making has several obvious benefits and is efficient. Research is increasingly being used to influence real-world planning and decision-making through a range of activities that have come to be known as Health Impact Assessment (HIA).[22,23]

There have only been a few studies to date that have incorporated health metrics into the scenario planning process. Two of those recently conducted by UD4H in California, each employing a different approach, are reviewed in this report. When health-related metrics are incorporated into the scenario planning process, it provides an opportunity to apply evidence on built environment relationships with health related outcomes to real-world planning decisions. Unlike most HIAs, which are commonly developed for a single use on one specific planning project, scenario planning is designed to test a broad range of planning and policy strategies. The California Public Health Assessment Model is applicable throughout California and at a range of geographic scales, from neighborhood to region.

Several advancements were made through this project, building on previous efforts and information found in the published academic literature. Lack of variation in urban form due to limited geography has been an obstacle in previous studies. Small sample size with limited statistical power has also inhibited efforts to quantify age and income-specific relationships between environments and health-related outcomes. Evidence makes it clear that people of different socio-demographic backgrounds have unique behavioral relationships with the environments in which they live work, and play.[24,25] This project addressed many of these limitations, using California-based evidence on health, travel, and built environment characteristics with unprecedented statewide variation. Evidence used for this project captured wide variation in urban settings, from the most intense, mixed, and walkable places in the state, to auto-oriented suburban areas, commercial zones, and other development conditions. Physical activity related health and built environment relationships were also modeled for a specific age and income cohorts.

## Scenario Planning Overview

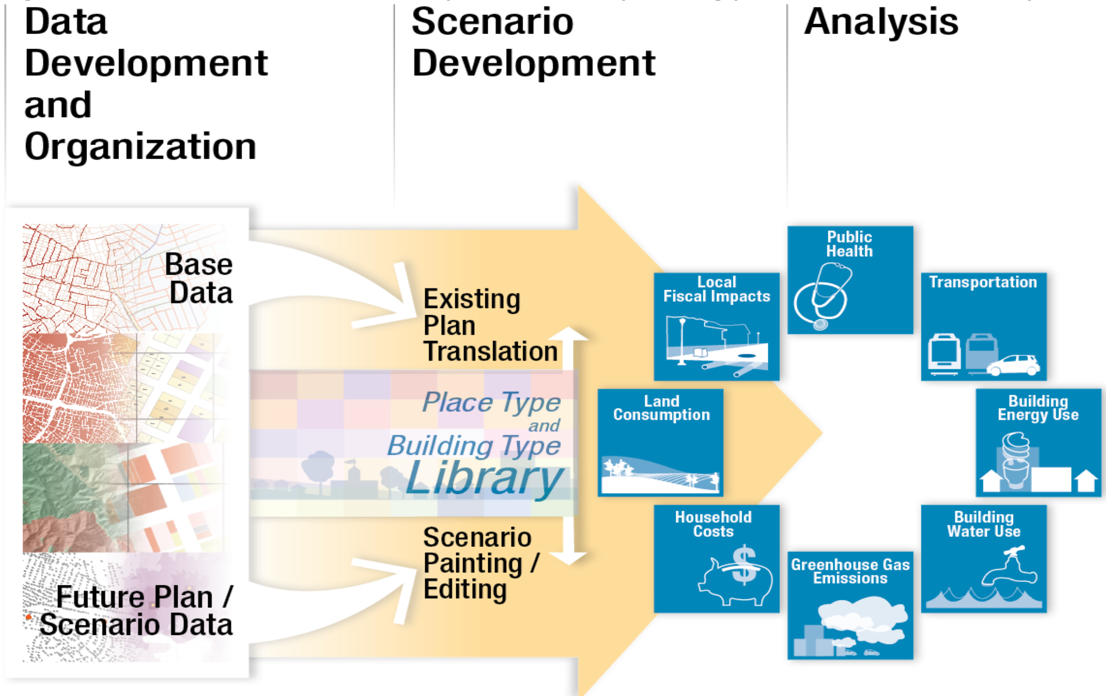
Over the past two decades *scenario planning* has evolved as a way for transportation and land use planners to evaluate travel, environmental, and economic impacts of community development or redevelopment. Scenario planning makes use of analytical tools to allow planners, decision makers, and the public to test assumptions about future conditions and receive feedback about the implications of those assumptions. Alternative scenarios and their impacts can be communicated to a wide range of audiences to educate stakeholders and inform planning, investment, and other policy decisions. While scenario planning can be conducted purely by technical staff, it is often incorporated into a larger public engagement process to communicate, educate, and provide a laboratory for testing recommendations from the public. Scenario planning can be conducted at a variety of scales, including state, regional, corridor, and neighborhood scales of analyses.

Scenario planning processes often take into account 3-5 alternative scenarios, typically projected to a common future date (e.g. a 20-year planning horizon). Scenarios often include a base case which calibrates data and models to existing conditions, and a “trend” or “business and usual” scenario that assumes existing conditions or adopted plans will remain unchanged in the future. The scenarios are often designed to understand the impact of planning/investments decisions and to develop strategies for achieving desired outcomes. Multiple future alternatives can be developed based on scenario planning objectives and interests, which are then compared to each other and to the trend or baseline scenarios.

Scenario-based planning with UrbanFootprint involves several stages as shown in Figure 3: data development and organization, including base data loading; scenario development, including plan translation and “painting” of scenarios; and scenario analysis.[1]

[1] For an overview of the process, see the document titled -- *UrbanFootprint Public Health Module: Existing Methods memo* (file name: ExistingMethods_Final_Apr14_2014.pdf)

Figure 2. Overview of the UrbanFootprint scenario planning process. Source: Calthorpe Analytics.




## Modeling Approach and Data Analysis

This section provides background information regarding the methodology and design of predictive health models for use in scenario planning application using the UrbanFootprint (UF) platform.

The following steps describe the data development, exploratory analysis, model development, validation, and application process:

### Data development

1. Collect UrbanFootprint built environment and demographic, California Health Interview Survey (CHIS), and California Household Travel Survey (CHTS) data sets
2. Apply exclusion criteria to CHIS and CHTS samples
3. Join UF data to CHIS and CHTS participant residential locations
4. Calculate neighborhood built environment variables for each CHIS/CHTS participant

### Exploratory data analysis

1. Generate descriptive statistics for proposed model variables and identify and address outliers and missing/erroneous data points
2. Analyze variable distributions and apply variable transformations as needed to meet model assumptions
3. Test for spatial autocorrelation

### Model development

1. Stratify the sample into population subgroups of interest
2. Identify outcome variables for modeling
3. For each model, select appropriate predictor variables
    a. Fit base models using demographic/socioeconomic covariates
    b. Add built environment variables
4. Fit models for each outcome, stratified by population subgroups

### Model validation

1. Predictive validation,
2. Aggregation-scale
3. A cross-year (2005 and 2009) validation procedure with CHIS models
4. CHIS predictions comparison to BRFSS outcomes
5. CHTS predictions comparison to NHTS outcomes.

Data development and exploratory analysis are described in the next section, organized by major data sources. Model development is outlined in the following section, and then the five model validation methods are outlined.

## Data Development and Exploratory Data Analysis

The predictive health models developed for this project used California-specific data sources from 30 counties across five California regions: the Bay Area, Sacramento, San Diego, San Joaquin Valley, and Southern California.

The choice of data, variables, and models sought to maximize representativeness of the demographics, socioeconomic status, behaviors, and health conditions of Californians as possible. In addition to leveraging land use data included in UrbanFootprint, the Public Health Assessment Model draws heavily from the California Health Interview Survey (CHIS) and the California Household Travel Survey (CHTS). Combining these two local data sources with built environment data has a number of benefits including:

- **Large sample size** – the 2009 CHIS (40,617 participants) and the 2010-2012 CHTS (53,733 participants) each represent a huge sample of households distributed across the 5-region study area. The large sample size provides the ability of finding statistically significant associations between variables and provides opportunities for stratifying the sample into population subgroups.
- **California-specific evidence** – the CHIS and CHTS data were collected from a representative cross-section of Californians, meaning that the models developed using these data will be generalizable to the population characteristics and health-related behaviors found in California.
- **Variability in built environment characteristics** –extensive and diverse geographical coverage ranging from downtown San Francisco to the most sprawling areas of the San Joaquin Valley increases the likelihood of identifying statistically significant health-related environmental

predictors and to ensure that the models are representative of the range of development types found across California.

- **Strata-specific model development** – the large sample size allowed for stratification and model development for relevant population segments (e.g., age or household income). Past evidence makes it clear that people of differing age, income (and gender) have uniquely different behavioral relationships with their physical environments; it therefore makes sense that health related outcomes would differ as well.

## UrbanFootprint (UF) Built Environment Data

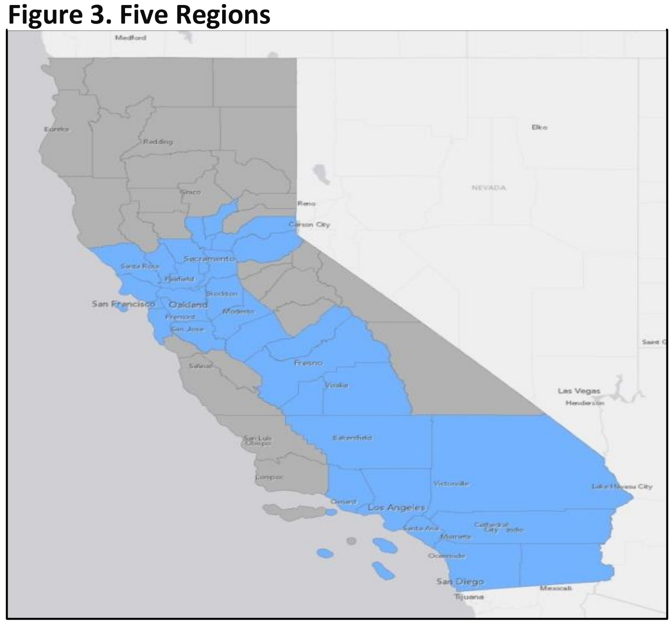
The Public Health Module builds off the following data developed by Calthorpe Analytics within UrbanFootprint:

- **Parcel/grid-level data** (cells equal to 150m square units or 5.5 acres) included regional land use classification; UF built form type; housing unit count by housing type; employee count by sector; building floor area by land use type; and land area by land use type.
- **Transportation system** shape files from UF including intersection locations, street networks, fixed-rail transit locations
- **Census and American Community Survey** Data were used to created population profiles at the grid cell for age, sex, race/ethnicity, educational attainment, employment status, household income, average household vehicle availability, average household size, and renter/owner status

These data were developed for 5 California metropolitan planning organization regions, encompassing 30 counties:

- SACOG (Sacramento region)
- SANDAG (San Diego County)
- SCAG (including Los Angeles)
- San Francisco Bay Area
- San Joaquin Valley regions

**Figure 3. Five Regions**




Additional built environment data was developed or summarized specifically for the health models including:

- Intersection density, local street length, major street length, dwelling unit count, residential density, retail building floor area, non-residential floor-to-area ratio, land use mix capturing entropy of 5 land use categories, bus stop count, rail stop count, any transit stop count, and park or open space area (each of these were calculated within 1km airline buffers of each grid cell)
- Distance (truncated at 2km) to nearest retail use, restaurant use, educational use, park or open space, rail stop, bus stop (truncated at 1km), any transit stop, and freeway.

- Presence or absence of rail access within 2km, bus access within 1km, and major road exposure within 500m.
- Regional accessibility measuring residential accessibility and employment accessibility

Because built environment variables are highly correlated, variance inflation factors were used to quantify multicollinearity in modeling transport walking and recreational physical activity from the CHTS. Variables within single domains (i.e. intersection density and local street length) with high correlation were combined into composite variables: mixed use, rail access, school distance, residential access, commercial access, park access, regional access, connectivity index, transit access and major road index. Some multicollinearity remained, prompting the creation of a walkability index weighted to account for relative differences in explaining CHTS transportation walking.

## California Health Interview Survey (CHIS)

The California Health Interview Survey (CHIS) is the largest regularly-conducted health survey in the United States, with surveys conducted every other year between 2001 and 2009 and continuously in two year waves since 2011. Each CHIS survey consists of three unique instruments – one each for adults (18 and older), teens (12-17), and children (11 and younger). These data provide individual health-related behaviors, health outcomes, and relevant covariates. Due to both close temporal match and the comprehensive nature of physical activity variables, the California Public Health Assessment Model uses 2009 CHIS data. Note that the 2005 wave was used for cross-year validation (see Validation section).

Individuals who lived within the 30 county region, were currently able to walk, were not pregnant, and who had usable geocoded locations were included in the model. There were 40,617 individuals included in the models. Table 1 shows the breakdown of the sample by region.

**Table 1: CHIS sample size by region**

| Bay Area | SACOG | SANDAG | San Joaq. Valley | SCAG | Total |
|---|---|---|---|---|---|
| 9,446 | 4,006 | 5,239 | 4,988 | 16,938 | 40,617 |

The sample was cross-classified by age and household income groups, with sample sizes as follows:

**Table 2: CHIS sample size by region, by age/income**

| | Household income groups: | | | |
|---|---|---|---|---|
| Age groups: | All | Low (<$35k) | Med ($35-100k) | High (>$100k) |
| All (5+) | 40,617 | 17,669 | 11,173 | 11,775 |
| Children (5-11) | 3,117 | 1,159 | 757 | 1,201 |
| Teens (12-17) | 2,367 | 874 | 583 | 910 |
| Adults (18-64) | 23,515 | 9,188 | 6,537 | 7,790 |
| Seniors (65+) | 11,618 | 6,448 | 3,296 | 1,874 |

Covariates brought in from CHIS included age, sex, race/ethnicity, disability status, adult/parent educational attainment, adult/parent employment status, adult/parent homeownership, household income, household size, and presence of children. A sample of descriptive statistics for adult covariates is provided in Table 3 below:

**Table 3. CHIS adult covariate descriptive statistics. (mean values or percentages)**

| | Pooled | By Income group | | | By Region | | | | | By Disability Status | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | All | Low | med | high | Bay Area | SACOG | SANDAG | SCAG | SJV | none | ambulatory | other |
| Age | 46 | 44 | 47 | 48 | 48 | 46 | 47 | 46 | 44 | 45 | 52 | 46 |
| Male % | 43% | 40% | 41% | 47% | 44% | 42% | 42% | 42% | 43% | 44% | 43% | 38% |
| Hispanic | 23% | 39% | 16% | 9% | 10% | 15% | 21% | 28% | 37% | 22% | 26% | 22% |
| White | 56% | 37% | 63% | 72% | 64% | 70% | 63% | 47% | 52% | 56% | 50% | 58% |
| Asian | 14% | 14% | 13% | 14% | 20% | 8% | 9% | 16% | 5% | 15% | 16% | 8% |
| Other | 8% | 9% | 8% | 5% | 6% | 8% | 7% | 9% | 7% | 7% | 8% | 12% |
| HS diploma or less | 31% | 53% | 24% | 11% | 21% | 31% | 26% | 33% | 46% | 28% | 42% | 37% |
| Some college | 25% | 27% | 30% | 19% | 22% | 30% | 26% | 25% | 27% | 23% | 28% | 32% |
| Bachelor's or higher | 44% | 20% | 46% | 70% | 57% | 39% | 48% | 41% | 27% | 48% | 30% | 31% |
| Employed % | 64% | 49% | 69% | 77% | 68% | 63% | 65% | 62% | 60% | 70% | 52% | 41% |
| Home owner % | 65% | 39% | 74% | 87% | 67% | 69% | 66% | 61% | 65% | 68% | 54% | 57% |
| HH income < $50k | 39% | 100% | 0% | 0% | 28% | 38% | 36% | 43% | 51% | 33% | 55% | 57% |
| HH income $50-150k | 28% | 0% | 100% | 0% | 27% | 32% | 29% | 27% | 28% | 29% | 24% | 24% |
| HH income > $150k | 33% | 0% | 0% | 100% | 46% | 30% | 35% | 30% | 20% | 38% | 21% | 19% |
| HH size | 3.0 | 3.1 | 2.8 | 3.0 | 2.7 | 2.8 | 2.9 | 3.1 | 3.3 | 3.1 | 2.5 | 2.9 |
| Any children present | 43% | 44% | 38% | 45% | 39% | 40% | 40% | 44% | 51% | 46% | 40% | 28% |
| Ambulatory disability | 15% | 22% | 13% | 8% | 12% | 17% | 15% | 15% | 17% | 0% | 100% | 0% |
| Other disability | 11% | 16% | 10% | 7% | 11% | 12% | 11% | 11% | 12% | 0% | 0% | 100% |

Health outcomes for adults/seniors included:

- **Physical Activity** (converted into METs when possible for obesity models)
    - Variable categories included transportation walking, recreational walking, recreational moderate activity (excludes walking) and recreational vigorous activity
    - To address zero-inflated distributions, each category was divided into binary (yes or no activity) and two continuous components (minutes and metabolic equivalent).
- **Obesity** - Body mass index; with two categorical variables for overweight or obese, and obese, but not overweight
- **Health outcomes**
    - **High blood pressure** (if ever diagnosed by a doctor)
    - Presence of **heart disease** (if ever diagnosed by a doctor)
    - Type II **Diabetes** (if ever diagnosed by a doctor)
    - **Self-reported poor/fair health** (versus good/very good/excellent)

Health outcomes for children and teens varied slightly:

- **Physical activity** was calculated as the number of days with at least 60 minutes of physical activity in the last week and any walking/biking to school during past week.
- **Obesity** measures are based upon BMI index percentiles.
- **Health outcomes** were limited to self-report poor/fair health.

Outliers were identified for continuous variables (physical activity duration times and BMI values). The upper threshold was set to equal the 75$^{th}$ percentile log(value) + 1.5 * interquartile range for each variable. Values falling above the 75$^{th}$ percentile were set at the upper threshold. A similar procedure was performed on low BMI values, setting the minimum to the 25$^{th}$ percentile. Table 5 provides descriptive statistics of health outcomes for the adult cohort.

**Table 4. CHIS adult outcome descriptive statistics. (mean values or percentages)**

| | Pooled | By Income group | | | By Region | | | | | By Disability Status | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | All | low | med | high | Bay Area | SACOG | SANDAG | SCAG | SJV | none | ambulatory | other |
| Walking – transp. (% with any) | 48% | 53% | 45% | 46% | 54% | 42% | 46% | 49% | 42% | 49% | 41% | 51% |
| Walking - rec. (% with any) | 62% | 56% | 63% | 68% | 65% | 61% | 65% | 62% | 56% | 65% | 51% | 59% |
| Moderate PA (% with any) | 57% | 52% | 59% | 62% | 59% | 61% | 60% | 55% | 58% | 60% | 47% | 57% |
| Vigorous PA (% with any) | 32% | 25% | 32% | 41% | 37% | 33% | 33% | 31% | 27% | 36% | 16% | 29% |
| Walking – transp. (min/wk) | 54.3 | 66.6 | 49.7 | 43.6 | 59.9 | 47.6 | 49.4 | 55.5 | 49.9 | 54.2 | 47.5 | 63.7 |
| Walking - rec. (min/wk) | 83.6 | 74.0 | 84.5 | 94.2 | 93.4 | 79.9 | 91.4 | 81.5 | 67.6 | 87.2 | 66.1 | 83.2 |
| Moderate PA (min/wk) | 109.6 | 103.3 | 108.9 | 117.6 | 109.9 | 130.1 | 115.0 | 101.0 | 116.1 | 111.3 | 100.3 | 110.9 |
| Vigorous PA (min/wk) | 58.2 | 46.4 | 57.3 | 73.0 | 64.9 | 57.3 | 59.9 | 56.1 | 52.1 | 65.2 | 28.8 | 51.1 |
| BMI | 26.8 | 27.6 | 26.8 | 26.0 | 26.0 | 27.5 | 26.8 | 26.7 | 28.4 | 26.3 | 29.1 | 27.1 |
| Overweight % | 33% | 32% | 32% | 34% | 31% | 34% | 33% | 33% | 35% | 33% | 33% | 31% |
| Obese % | 23% | 28% | 24% | 18% | 18% | 28% | 23% | 23% | 33% | 20% | 25% | 38% |
| High BP % | 25% | 28% | 25% | 22% | 23% | 26% | 25% | 26% | 29% | 21% | 30% | 44% |
| Heart disease % | 5% | 6% | 4% | 4% | 4% | 5% | 4% | 5% | 5% | 3% | 6% | 12% |
| Type 2 diabetes % | 6% | 8% | 6% | 4% | 5% | 5% | 6% | 7% | 7% | 4% | 7% | 14% |
| Poor health % | 18% | 32% | 12% | 6% | 15% | 15% | 14% | 20% | 23% | 10% | 30% | 47% |

## California Household Travel Survey

The CHTS consists of several survey components, including a telephone survey, a 24-hour travel diary, and for a subsample, three days wearing a global positioning satellite (GPS) device. After applying the exclusion criteria, the final analytical sample consisted of 53,733 individuals. Participants were distributed by region as follows:

| Bay Area | SACOG | SANDAG | San Joaq. Valley | SCAG | Total |
|---|---|---|---|---|---|
| 14,739 | 3,134 | 2,777 | 8,890 | 24,193 | 53,733 |

When cross-classified by age and household income groups, the sample sizes are as follows:

| | Household income groups: | | | |
|---|---|---|---|---|
| Age groups: | All | Low (<$50k) | Med ($50-100k) | High (>$100k) |
| All (5+) | 53,733 | 16,933 | 17,068 | 19,732 |
| Children (5-11) | 4,829 | 1,670 | 1,378 | 1,781 |
| Teens (12-17) | 4,734 | 1,479 | 1,270 | 1,985 |
| Adults (18-64) | 35,695 | 10,593 | 11,283 | 13,819 |
| Seniors (65+) | 8,475 | 3,191 | 3,137 | 2,147 |

These data were used to derive individual participation in transportation and recreational physical activity. Components of the CHTS data set used in the analysis included the following:

- **Geocoded household, trip, and activity location shapefile**
- **Covariates/ household and individual characteristics** - age, sex, race/ethnicity, educational attainment, adult employment status, home ownership, household income, household size, presence of children, disability status; for child and teen models, maximum household education attainment and count of persons employed in household.
- **Individual trip/activity records**

Travel survey records were modified to distribute simultaneous activities and then categorized as active travel for walk and bike trips and recreational activity. Loop trips (i.e. walking around the neighborhood) were cleaned and assigned as recreational activity and outlier trips or times were addressed. This allowed all trips to be aggregated by individuals into relevant categories. To address skewness, non-zero data was log-transformed. Table 5 (covariates) and Table 6 (physical activity outcomes) provide descriptive statistics for various age cohorts.

**Table 5. CHTS covariate descriptive statistics by age group. (mean values or percentages)**

| Variable | seniors | adults | teens | children |
|---|---|---|---|---|
| Age | 73 | 46 | 15 | 8 |
| Male % | 49% | 49% | 52% | 50% |
| Hispanic | 14% | 25% | 36% | 41% |
| White | 76% | 62% | 53% | 46% |
| Asian | 5% | 8% | 7% | 8% |
| Other | 6% | 6% | 4% | 5% |
| HS diploma or less* | 12% | 12% | 17% | 20% |
| Some college* | 26% | 25% | 24% | 22% |
| Bachelor's or higher* | 61% | 62% | 60% | 58% |
| Employed %* | 27% | 72% | - | - |
| Home owner %* | 88% | 77% | 78% | 70% |
| HH income < $50k | 38% | 30% | 31% | 35% |
| HH income $50-100k | 37% | 32% | 27% | 29% |
| HH income > $100k | 25% | 39% | 42% | 37% |
| HH size | 2.314 | 3.2 | 4.4 | 4.7 |
| % with any child <18* | 4% | 35% | 100% | 100% |
| HH vehicles | 1.835 | 2.1 | 2.2 | 2.0 |
| Ambulatory disability | 11% | 3% | 1% | 0% |
| Other disability | 8% | 3% | 1% | 1% |

* For teens/children, statistics are for surveyed parents and education is max in household

**Table 6. CHTS outcome descriptive statistics by age group. (mean values or percentages)**

| Variable | seniors | adults | teens | children |
|---|---|---|---|---|
| Walking – transp. (% with any) | 10% | 15% | 24% | 21% |
| Biking – transp. (% with any) | 1.1% | 2.2% | 4.4% | 2.4% |
| Auto travel (% with any) | 74% | 83% | 77% | 81% |
| Recreational PA (% with any) | 17% | 17% | 22% | 25% |
| Walking – transp. (min/day) | 3.4 | 5.0 | 7.3 | 5.1 |
| Biking – transp. (min/day) | 0.6 | 1.2 | 1.5 | 0.8 |
| Auto travel (min/day) | 61 | 75 | 48 | 51 |
| Recreational PA (min/day) | 18 | 18 | 35 | 34 |

## Model Development

For each outcome, one model was generated for each age group with all income groups pooled together. Three additional models were generated for adults after stratifying the sample into the three income groups: <$50,000, $50,000-$100,000, >$100,000. Table 7shows the outcomes modeled, dataset used, ability to model for various age groups, the regression procedure used, and an indication of the model was adjusted for transportation walking, physical activity, and/or BMI.

**Table 7: Preliminary models by age**

| | Age cohort | | | | Adjusting for: | | | |
|---|---|---|---|---|---|---|---|---|
| Data set | Adult/ senior | Teen/ child | Outcome | Regression | Dem /SES | Tr. walk | PA | BMI |
| CHIS | both | | Walking - trans. (min/wk) | Two-part | x | | | |
| CHIS | both | | Walking - rec. (min/wk) | Two-part | x | x | | |
| CHIS | both | | Moderate PA (min/wk) | Two-part | x | x | | |
| CHIS | both | | Vigorous PA (min/wk) | Two-part | x | x | | |
| CHIS | | both | Days/week > 60 min PA | Poisson | x | | | |
| CHIS | | both | Likelihood to walk/bike from school | Binary | x | | | |
| CHIS | both | both | BMI / BMI% | Linear | x | | x | |
| CHIS | both | both | Likelihood to be overweight/obese | Binary | x | | x | |
| CHIS | both | both | Likelihood to be obese | Binary | x | | x | |
| CHIS | both | | Likelihood to have high BP | Binary | x | | x | x |
| CHIS | both | | Likelihood to have heart disease | Binary | x | | x | x |
| CHIS | both | | Likelihood to have type 2 diabetes | Binary | x | | x | x |
| CHIS | both | both | Likelihood to have poor health | Binary | x | | x | x |
| CHTS | both | both | Walking for transport. (min/day) | Two-part | x | | | |
| CHTS | adults | | Biking for transport. (min/day) | Two-part | x | | | |
| CHTS | both | both | Auto travel (min/day) | Two-part | x | | | |
| CHTS | both | both | Recreational PA (min/day) | Two-part | x | x | | |

Two-part regression indicates that the model was split into two parts. In the first, binary logistic regression was used to model the likelihood of any activity versus no activity. In the second, linear regression was used to model the amount of activity in minutes for only the portion of the sample with any activity.

All demographic and socioeconomic covariates listed previously were tested for inclusion in every model. Additionally, all recreational physical activity models adjusted for whether a participant engaged in any transportation walking. All BMI/overweight/obesity models adjusted for total metabolic equivalent (MET)-minutes of physical activity (the sum of MET-minutes of transportation walking, recreation walking, moderate PA, and vigorous PA). Finally, the four health outcome models adjusted for total minutes of physical activity and BMI (for adults/seniors) or BMI% (for teens/children).

Two separate modeling processes were completed for each model. First, each built environment variable was added one-at-a-time to a model that adjusted for all applicable covariates. This provided information about each built environment variable when isolated from potential impacts of multicollinearity. Next, all built environment variables were added simultaneously to a model that adjusted for all applicable covariates. Finally, a variable selection process was conducted to remove covariates and built environment variables that, when removed, improved the Aikake information criterion (AIC, a metric indicating relative model fit) by at least 1.[2] This was accomplished by calculating the change in AIC that would occur from removing each individual variable, removing the variable that would result in the largest reduction in AIC (so long as the reduction was >1), then repeating until removing the variable that would result in the largest reduction in AIC would only reduce the AIC by <=1.

## Validation Procedures

In order to understand the validity of the models, five different validation exercises were performed:

- predictive validation metrics,
- aggregation-scale metrics;
- cross-year (2005 and 2009) validation procedure with CHIS models;
- comparison of CHIS predictions to BRFSS outcomes; and
- comparison of CHTS outcomes to NHTS outcomes.

Each of the validation procedures are described below.

## Predictive validation metrics

To simulate the effect of changing built environment characteristics, two predictive modeling scenarios were developed:

1. <u>Base scenario</u>: Variable values were identical to values used for model fitting.
2. <u>Change scenario</u>: All covariates were held constant, while built environment variables were revised to simulate the effect of presumed "healthful" changes in the built environment.

Change in built environment variables was derived by first calculating a 1 decile difference (between the 5th and 6th deciles) for each built environment variable for the CHIS and CHTS samples, then adding (or subtracting) that value from the base built environment variable for each participant. Because this approach did not work for the two dichotomous built environment variables, the difference for these variables was calculated as 1/10th of the percent of participants currently "exposed" to the built environment variable. For example, 9.7% of CHTS participants currently have rail access within 2km, so the change scenario difference was calculated to be 0.97%.

Upon applying the differences to each participant's base built environment variable values, if the application of a "negative" built environment value resulted in a negative value, the change value was

[2] Burnham KP, Anderson DR. Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach, 2nd ed. Springer-Verlag. 2002.

recoded to equal zero. For example, a participant with 0 miles of major road within 1km would continue to have 0 miles in the change scenario, rather than -0.1 miles.

Mean observed outcome, mean base scenario predicted outcome, mean change scenario predicted outcome, and the absolute and percent differences between the base and change predicted outcomes were derived. Because the same data were used for fitting and testing the models, we expected the mean sample observed outcome and mean base predicted outcomes to be very similar. The largest error between the mean sample observed outcome and mean base predicted outcome for CHIS models was 2.6% for adult diabetes, and in the majority of cases, the error was less than 1%.

## Aggregation scale validation metrics

Validation metrics were also produced by aggregating predictions to a variety of spatial scales (Census tracts, zip codes, and counties). This demonstrated the improvement in predictive accuracy obtained by aggregating predictions to larger spatial units where model errors increasingly cancel one another out. Based on the available sample sizes, our county-level predictions are most equivalent to the accuracy we might expect from applying the models at the Census block group level, which range in size from 600-3,000 people.

## CHIS cross-year validation metrics

The CHIS models, which were developed, using 2009 CHIS data, were applied to 2005 CHIS data to validate the results with a second CHIS data set that was not used for model fitting. In terms of the variables used in the draft CHIS models, the 2005 CHIS data set is nearly identical. One exception is that data were not collected in 2005 on children's physical activity participation. For all other CHIS model outcomes, cross-year validation metrics were calculated.

To do so, the 2005 CHIS data were first developed identically to the 2009 CHIS data. All variables were coded identically, exclusion criteria were applied identically, and 2005 CHIS participants were matched to UF grid cells to derive built environment characteristics for each participant.

Because the 2005 data set was not used for fitting the models, we expected the prediction error to be higher when applying the models to the 2005 data set, in comparison to applying the models to the 2009 data set. Temporal mismatches (e.g. differences in external conditions[3]/events between 2005 and 2009 that may affect CHIS covariate and outcome values; and between 2005 CHIS data collection and more recent UF built environment data collection) both contribute to increased error when applying the models to 2005 CHIS data.

[3] Note: that built environment variables used for 2005 CHIS participants are from the same UF base year as used to develop the models - built environment data are not available for earlier years.

As expected, results indicated more prediction error when applying the models (fit with 2009 data) to the 2005 data set than when applied to the 2009 data. The largest error was a 17% under-prediction for adult transportation walking, though in the majority of cases, error was less than 5%. For comparison, the largest error when applying the models to the 2009 data set was 2.6% for adult diabetes, and in the majority of cases, the error was less than 1%. Mean absolute error / mean outcome ratio was marginally higher when applying the models to the 2005 data set (~0.1 on average) than to the 2009 data set (~0.07 on average). For any differences identified between the BRFSS results and CHIS-based model predictions, there is no way to determine from these data which data set provides the more accurate measurement.

## CHIS validation with Behavioral Risk Factor Surveillance Survey

The latest Behavioral Risk Factor Surveillance Survey (BRFSS) data (from 2012) were summarized and compared to UF model predictions to further validate the CHIS-based models. However, like the CHIS, BRFSS is also a self-reported survey representing only a small sample of California residents. Data collection methodologies, variable definitions, and sample composition differed to some extent between both surveys.

BRFSS data are available at the individual level but the smallest geographic identifier provided for each BRFSS participant is the county. Only adult and senior data are available through the BRFSS. Those currently pregnant were removed from the BRFSS data, to match the exclusion criteria for the CHIS models. None of the other CHIS model exclusion variables were available through the BRFSS. Using person weights provided by the BRFSS, relevant outcome variables (i.e. those identical or similar to those used for the CHIS models) were weighted at the individual level and aggregated to the county level. For outcome variables that matched identically between the BRFSS and CHIS data sets, county-level outcomes were compared and the following summary statistics were calculated (Table 8 and Table 9):

- Predicted correlation: this was derived by calculating the Pearson's correlation between predicted and observed outcomes at the spatial unit level. Correlation ranges from -1 to 1, where -1 is perfect negative correlation, 0 is no correlation, and 1 is perfect correlation.
- Mean absolute error: for each spatial unit, the mean observed value was subtracted from the mean predicted value and converted to an absolute value, and then the mean value of these absolute differences was calculated. This metric indicates the magnitude of the average error for each model, and is in the same units as the outcome value. This was only calculated for counties with a BRFSS sample size >= 30.
- Mean absolute error/mean outcome: to allow for easier comparison across different models, this metric divides the mean absolute error by the mean outcome value. This can also be thought of as the mean absolute error percentage for each outcome. This was only calculated for counties with a BRFSS sample size >= 30.

For the four outcomes shown in the tables below, the predicted correlations are higher for adults, than for seniors, ranging from 0.37 for percent of people overweight to 0.75 for BMI values. Similarly, the mean absolute error is lower for adults than seniors, except in the case of BMI.

**Table 8: Adult UF prediction – BRFSS observed difference**

| | UF prediction – BRFSS observed difference | | | |
|---|---|---|---|---|
| Metric | BMI | % Overweight | % Obese | % Poor health |
| Predicted correlation | 0.75 | 0.37 | 0.66 | 0.59 |
| Mean absolute error | 0.70 | 4.5% | 5.7% | 3.3% |
| Mean absolute error / mean outcome ratio | 0.03 | 0.14 | 0.20 | 0.25 |

**Table 9: Senior UF prediction – BRFSS observed difference**

| | UF prediction – BRFSS observed difference | | | |
|---|---|---|---|---|
| Metric | BMI | % Overweight | % Obese | % Poor health |
| Predicted correlation | 0.51 | 0.26 | 0.14 | 0.28 |
| Mean absolute error | 0.62 | 5.8% | 8.4% | 7.7% |
| Mean absolute error / mean outcome ratio | 0.02 | 0.20 | 0.34 | 0.30 |

## CHTS validation with National Household Transportation Survey

The latest National Household Travel Survey (NHTS) data (from 2009) were summarized and compared to UF model predictions to further validate the CHTS models. However, like the CHTS, NHTS is a self-reported survey representing only a small sample of California residents. Data collection methodologies, variable definitions, and sample composition differed to some extent between both surveys. For any differences identified between the NHTS results and CHTS-based model predictions, there is no way to determine from these data which data set provides the more accurate measurement. Ideally, we should find similar results between the two data sets.

NHTS data are available at the individual level and a variety of geographic identifiers are provided for each NHTS participant. Because of the small sample sizes available at smaller geographic levels, NHTS data were used at the county level. Using person weights provided by the NHTS, relevant outcome variables (i.e. those identical or similar to those used for the CHIS models) were weighted at the individual level and aggregated to the county level. The tables below summarize the weighted mean outcome values at the county level for the 30 counties in the UF study area. Data was not available in the NHTS on recreational physical activity engagement.

For any outcome variables that matched identically between the NHTS and CHTS data sets, county-level outcomes were compared and the following summary statistics were calculated predicted correlation, mean absolute error, and mean absolute error/mean outcome (Table 10and Table 11).[4]

**Table 10: Adult UF prediction – NHTS observed difference**

| | UF prediction – NHTS observed difference (for transportation, minutes/day) | | |
|---|---|---|---|
| Metric | walking | biking | auto |
| Predicted correlation | 0.85 | 0.55 | 0.29 |
| Mean absolute error | 2.17 | 0.70 | 12.64 |
| Mean absolute error / mean outcome ratio | 0.37 | 1.81 | 0.20 |

**Table 11: UF prediction – NHTS observed difference (for transportation, minutes/day)**

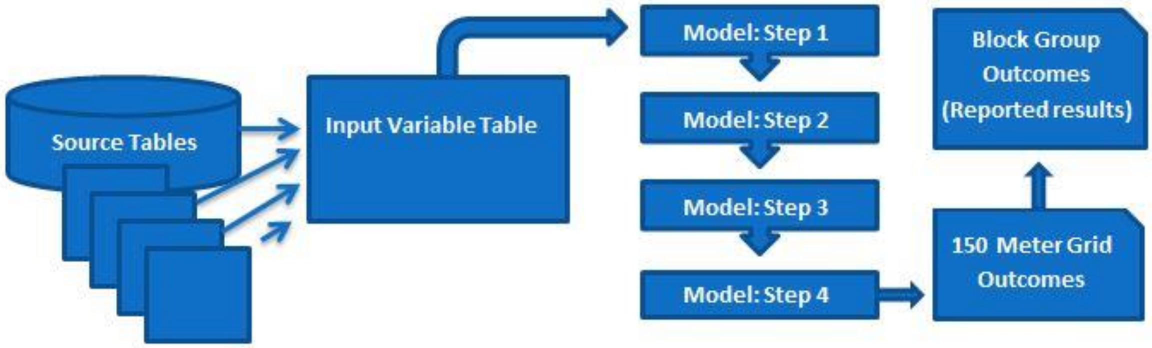
| | Senior | | Teen | | Child | |
|---|---|---|---|---|---|---|
| Metric | walking | auto | walking | auto | walking | auto |
| Predicted correlation | 0.88 | -0.05 | 0.32 | 0.18 | 0.05 | 0.15 |
| Mean absolute error | 2.13 | 5.50 | 4.32 | 4.61 | 2.90 | 8.13 |
| Mean absolute error / mean outcome ratio | 0.39 | 0.09 | 0.46 | 0.16 | 1.03 | 0.26 |

## Programming Models into UrbanFootprint

The programming of the public health incidence models into UrbanFootprint followed detailed specifications provided by UD4H. These specifications included the necessary definition for each input variable, any transformations that needed to be applied to the input variables, the sequence in which models needed to be run, any two-part calculations that needed to be derived, and the methods by which results needed to be aggregated. The module was scripted in a combination of Python, PostgreSQL, and SproutCore programming languages. The basic structure of how the module was programmed follows the diagram below.

[4] *Note: Validation metrics were generated only for the earlier version of the models before applying the corrections for multicollinearity problems. A review of validation metrics for the final models (after implementing the approach for dealing with multicollinearity) indicated that they would not differ substantively from those included in this report.*

**Figure 4: Public Health Module process diagram**




The models were provided to Calthorpe Analytics as individual CSV tables, with a separate rules spreadsheet that detailed the integration steps, column definitions, equations, and order of operations. Using this spreadsheet, the public health module was designed to be fully integrated with the existing architecture of the UrbanFootprint application. The following sections detail the process flow of the public health module as it was programmed and designed.

## Calculation of Input Variables

The first step in the process flow of the public health module is the calculation of all input variables to the individual physical activity and public health models. The process starts by normalizing all input datasets to the configured geographic unit of analysis (the default geographic unit of analysis is the 150 meter grid geography but other geographic scales can be configured). Attributes of various geographic scales and geography types are allocated to the unit of analysis based on their spatial location and on area of geographic intersection.

Once all data are normalized, the public health module begins calculating each model variable according to the required definitions. These definitions include a range of geographically derived variables that include distance proximities and buffered aggregations (e.g. distance to parks, distance to rail stops, people within ¼ mile). The input variable processes were programmed in Python and PostgreSQL languages. Given the computational resource requirements of these calculations, all geographic processes were configured to run in parallel.

The product of this process is a table containing the properly derived and named input variables for all models and derivative calculations at the configured geographic unit of analysis.

## Model Application

Once the input variable table has been created, all necessary data are staged for calculating the output for each public health model. There are four groups of physical activity and health models. Each group of models needs to be run in sequential order due to model outputs derived from group 1 are utilized by group 2, and model outputs form group 2 are utilized by group 3 models, and so forth. The Django Python-based web framework[5] is utilized for this process. Data from the created input variable table is passed from the PostgreSQL database into Python and the process then iterates over the rows of data, passing the values into a standardized Python dictionary. This dictionary is then passed to the class methods which handle the internal logic of ensuring each group of models is executed in the correct order and with the correct configurations.

The product of the model application is an outcomes table at the unit of analysis geography which contains the public health outcomes for all input table rows and all models.

## Standardized Result Tables

Having created the outcomes table at the selected geographic unit of analysis, the module then aggregates the results to the Census 2010 Block Group geography for reporting purposes. The Census block group geography was selected as the standardized reporting scale for visualizing and querying the public health module outcomes. That said, a project or user could decide that it is appropriate to aggregate grid or block group outputs to other geographies for reporting or dissemination of results. In the pilot testing, for example, while analysis was performed at the grid scale and aggregated to census block groups, results were also aggregated to custom subareas in Sacramento County (SACOG region), and to custom Scenario Planning Zones (SPZs) in Orange County (SCAG region).

Each model outcome is aggregated using population weights derived from the associated model outcome's age and income category. This ensures that the outcomes by age and income group are not biased by the aggregation methods. The aggregation method in the public health module is programmed in PostgreSQL, with configurations passed in with Python to carry out this operation.

In addition to the block group outcomes table, the module also produces an overall summary table of every physical activity and health model for the geographic extent being analyzed. The aggregation method applied to produce the overall summary table utilizes the same population weighted methodology as that of the block group summary table.

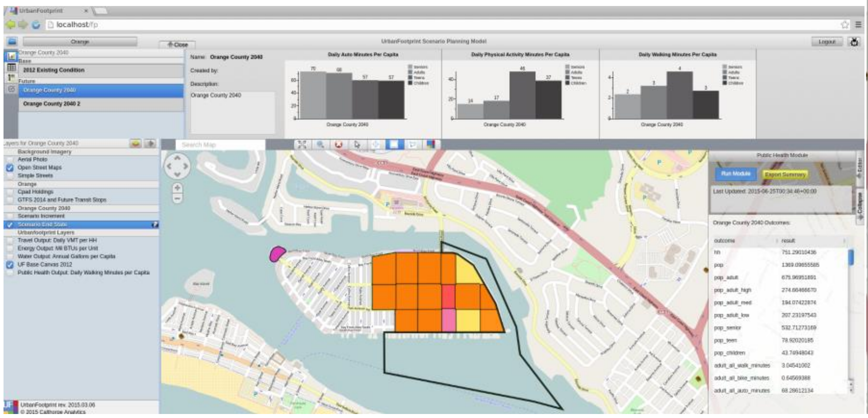
## UrbanFootprint User Interface

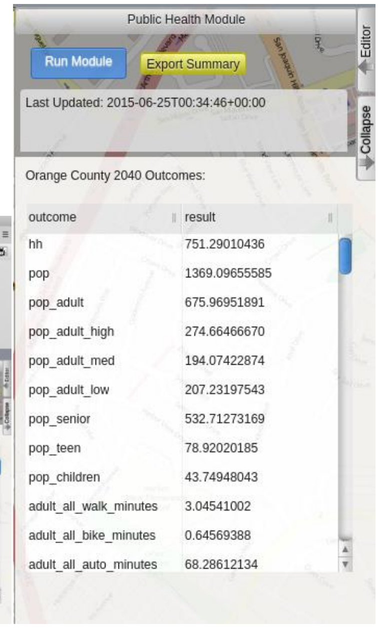
The complex logic of the backend programming of the physical activity and heath models has currently been embedded within the UrbanFootprint system. In addition, front end web-based functionality has been programmed so that the module can be executed on any region configured for UrbanFootprint use.

[5] https://www.djangoproject.com/

Features of the web-based application include the ability to paint new land use scenarios and to execute the public health module to review the physical activity and health impacts of changes in the built environment that include changes to street connectivity, residential density and mix, commercial density and mix, school location, park location, and transit location.

**Figure 5. UrbanFootprint User Interface**






The UrbanFootprint user interface includes a simple button to execute the module, a button to export a CSV summary of all results, charts with results by age category, and a table view of all aggregate results. In addition to these features, users can utilize the default functionality of UrbanFootprint version 1.3 to query the geographic public health results and export the block group results to an ESRI file geodatabase (.gdb).

The next section describes the results calculated by the final physical activity and health incidence models for two pilot application study areas.

# Pilot Testing the Public Health Assessment Model

Two counties were chosen for pilot testing:

- Sacramento County, one of six counties in the Sacramento Area Council of Governments (SACOG) region; and
- Orange County, one of six counties in the region covered by the Southern California Association of Governments (SCAG).

By focusing on these two counties, pilot testing explored the impacts of applying the model at different scales of geography (subareas and scenario planning zones), and varying methods for reporting model results.

Pilot testing used the UD4H finalized and validated models, which were integrated into the UrbanFootprint framework by Calthorpe Analytics. Testing focused on deploying the physical activity and health models for a base and future year in each of the pilot study areas. This section describes the pilot testing process and active transport and public health outputs in each of the regions. This is followed by a discussion of how to interpret and report the results of the public health models.

## Pilot #1 - Orange County

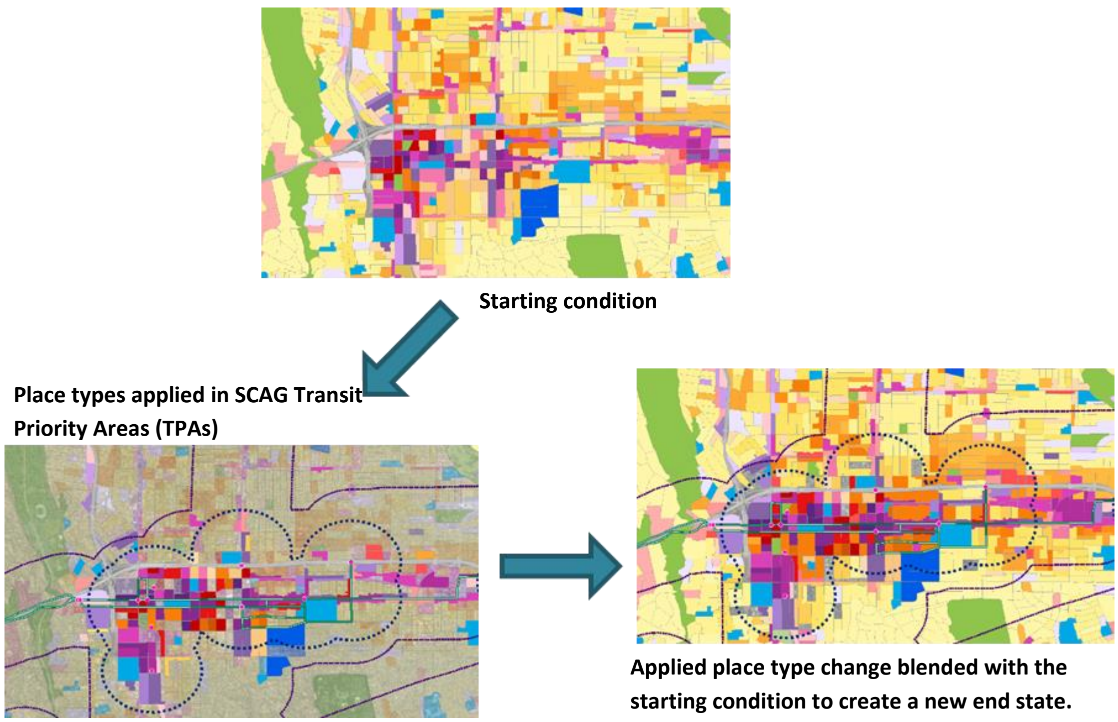
### Background

**Scenario Planning Zones (SPZs)** were the spatial unit of analysis used for the Orange County pilot. SPZs were designated by SCAG as an appropriate geography for regional planning activities at the outset of the process to develop the 2016 RTP/SCS. They are aggregations of parcels and vary in both size and residential and employment population. Land use is relatively uniform throughout a SPZ. There are approximately 250,000 SPZs in the six-county SCAG region, which aggregate approximately 4 million parcels. In Orange County, there are approximately 28,000 SPZs and 660,000 parcels.

Scenarios are built in UrbanFootprint using the application of place types. This process, as applied within the SCAG region with UrbanFootprint generally flows as illustrated in Figure 6 and Figure 7 below. Utilizing a detailed and standardized SPZ 'canvas' of built form, residential and commercial use, and street connectivity; change is applied via the allocation of place types . Once applied, place types are used to calculate new residential and commercial growth and changes in street connectivity using their density, use, and other characteristics.

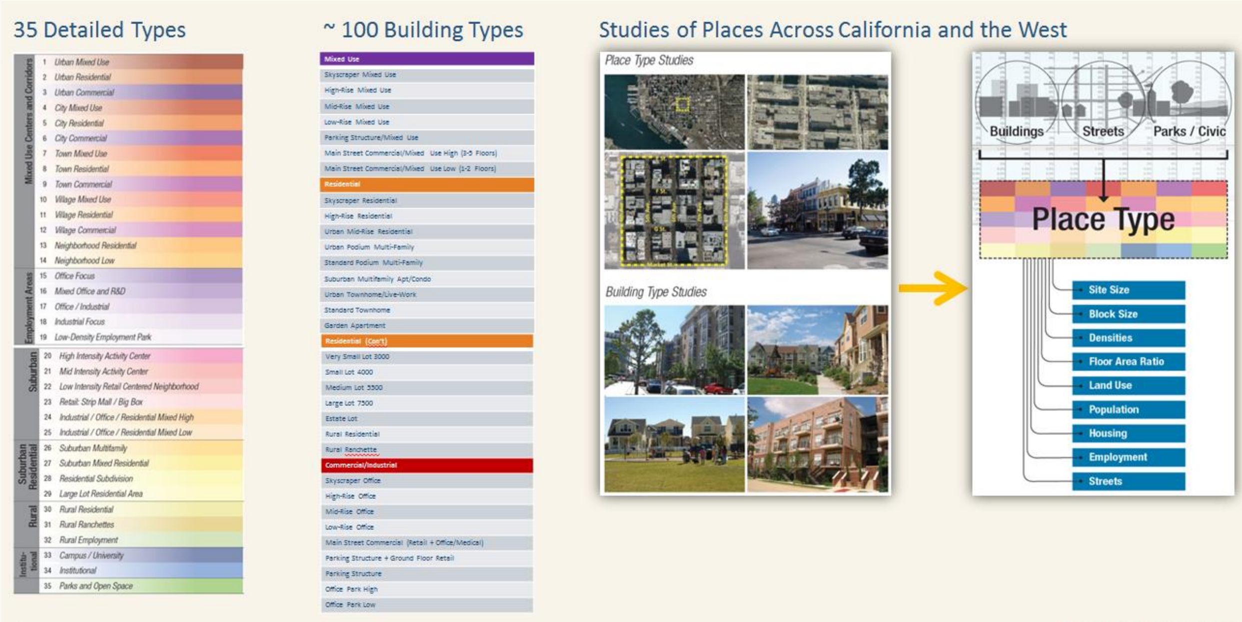
**Figure 6: The UrbanFootprint scenario development process**


**Figure 7: Example: applying change to SPZs via Place Types to increase density and walkability in Transit Priority Areas (TPAs)**




There are 35 Place Types in the SCAG UrbanFootprint library. As summarized in Figure 8, these types are made up of buildings, streets, parks, civic area, and other physical characteristics. They represent the complete range of development conditions in the Southern California region. They are built upon detailed studies of places across California and the west and pivot from the set of California-wide types developed as part of the Vision California process.

**Figure 8: SCAG UrbanFootprint place type summary**




The differences among the 35 detailed SCAG place types can be summarized according to a limited set of key qualities, as show in Figure 9 below. Each place type can be described according to key built environment characteristics, including density, mix of uses, and street connectivity (walkability). The place types vary in density, mix of uses, and street connectivity, as well as their specific location, proximity to transit, and access to regional jobs and other destinations. As an important summarizing step, UrbanFootprint classifies the 35 types into one of three Land Development Categories, or LDCs: Urban, Compact Walkable, and Standard Suburban.

**Figure 9: Summarizing place types as one of three Land Development Categories (LDCs)**


The 'Urban' type consists of the most mixed and intense concentrations of households and jobs. Street patterns are well-connected and walkable and transit service tends to be substantial in 'Urban' areas. The 'Compact Walkable' type has less density than Urban, but is highly walkable with a rich mix of uses. The 'Standard Suburban' LDC represents the majority of separate-use auto-oriented development and low walkability.

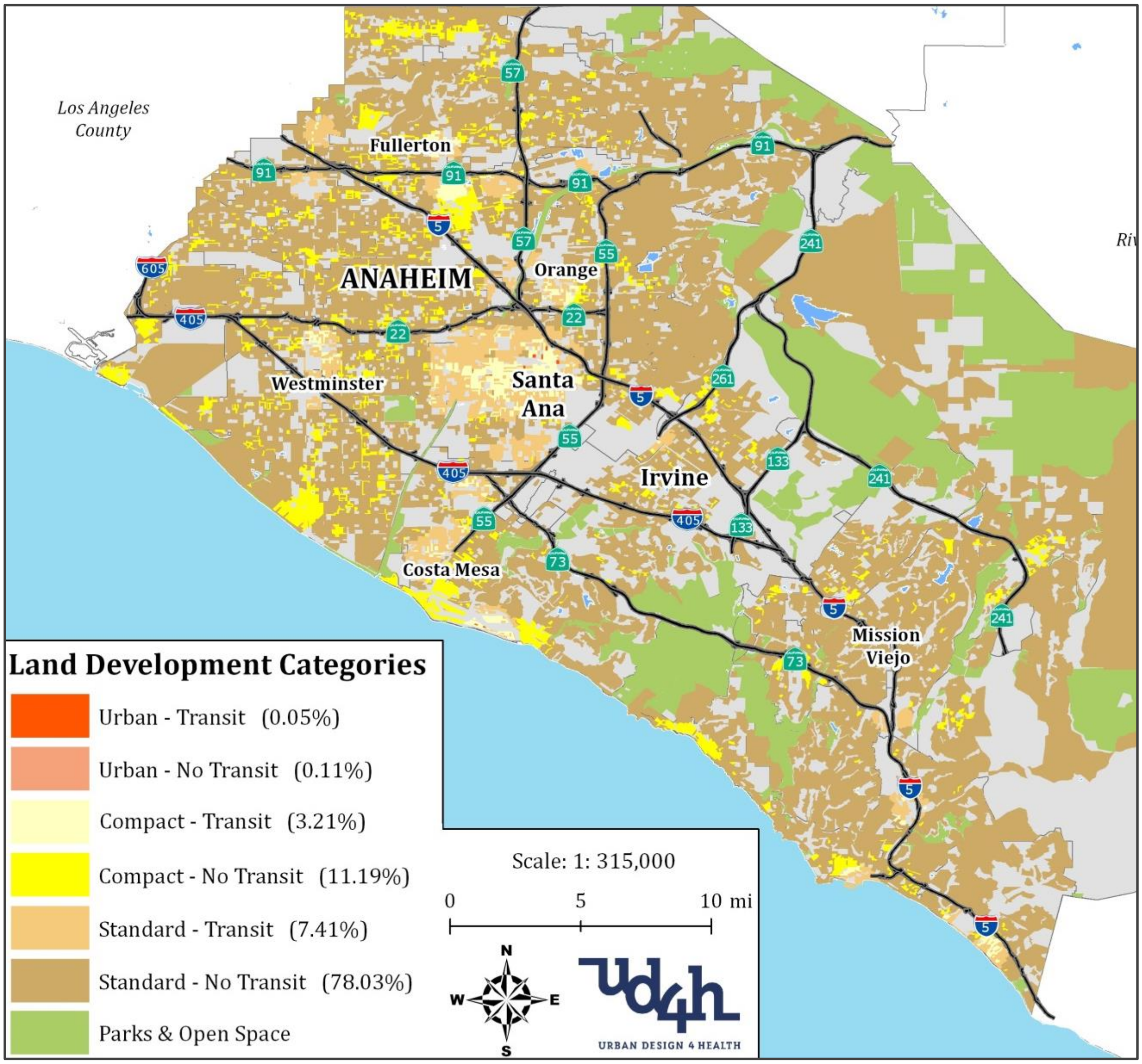
For the Orange County pilot, each SPZ in the county was assigned a **Land Development Category (LDCs)** based on built environment measures capturing residential density, employment density, and street connectivity, as described above and shown in Table 12 below. The presence/absence of transit was also added to support the modeling of transit access within the physical activity and health models.

**Table 12. Land Development Category Criteria**

| Land Development Category | Urban Form Criteria |
|---|---|
| **A) Urban Form** | |
| **Urban** | • Dwelling Units/Acre > 40 OR Employment/Acre> 70<br>• Intersection density (per mile) > 150 |
| **Compact Walkable** | • Dwelling Units/Acre < 40 AND Employment/Acre < 70<br>• Intersection density (per mile) > 150 |
| **Standard Suburban** | • Intersection density (per mile) < 150 |
| **B) Transit** | |
| **Yes** | • High quality transit stop/station within 1km of SPZ centroid |
| **no** | • High quality transit stop/station **NOT** within 1km of SPZ centroid |
| **High quality transit:** A rail stop or a bus corridor that provides or will provide at least 15-minute frequency service during peak hours | |

Figure 10 illustrates the distribution of SPZs across the five land development categories in the 2012 base year (Base Case). Over three-quarters of SPZs (78%) are categorized into the **Standard, No Transit** LDC.

**Figure 10. Land development categories assigned to Orange County SPZs (2012 Base Case)**




## Comparison Methodology

SPZs were assigned to a LDC based on the built environment conditions for two time points:

- Base Case (2012), and
- Future Scenario (2040)

These assignments facilitated base *versus* change comparisons for a consistent set of SPZs across the Orange County pilot area. For the purposes of comparison, the SPZ demographics remained the same between the base and future time points.

Changes to the built environment and presence of transit, as categorized by the LDC, resulted in over 20 pairs of base/future LDCs. This report highlights physical activity and health outcome differences between base and future time points for the five LDC pairs with the largest change in the built environment – going from a lower to higher level of development, with or without transit (Table 13). Reported outcome results reflect population-weighted means.

**Table 13. Orange County base case (2012) *versus* future case (2040) comparisons**

| LDC Comparison | Urban Form Change between 2012 and 2040 | Transit | # of SPZs |
|---|---|---|---|
| **1** | Compact (no change) | Future only | 106 |
| **2** | Standard to Compact | Future only | 51 |
| **3** | | No | 26 |
| **4** | Standard to Urban | Future only | 4 |
| **5** | | No | 6 |

Results from the Public Health Module were produced at for each SPZ by using the following age cohorts:

- Adults (18 – 64 years)
- Seniors ( > 65 years)
- Teens ( 12 – 18 years)
- Children (< 12 years)

## Results

The next section provides detailed information on one example comparison -- **Compact, Future Transit Only**. In this example there are 106 SPZs which at base and future time points are characterized as compact, AND which gain transit in the future. Additional details on the other four comparisons are provided in summary tables after the following section.

### *Comparison #1 – Compact (Base & Future), Future Transit Only*

Figure 11 shows the 106 SPZs that changed from the **Compact, No Transit** LDC (2012) to the **Compact, Transit** LDC (2040). Total population in the future case increased by 5.7% (Table 14), with the proportion of children less than 12 years old showing the largest gain (+7.6%).

**Figure 11. Spatial distribution of SPZs by LDC**

Brown is Comparison #1 -- Compact (Base & Future), Future Transit Only LDCs (n=106)

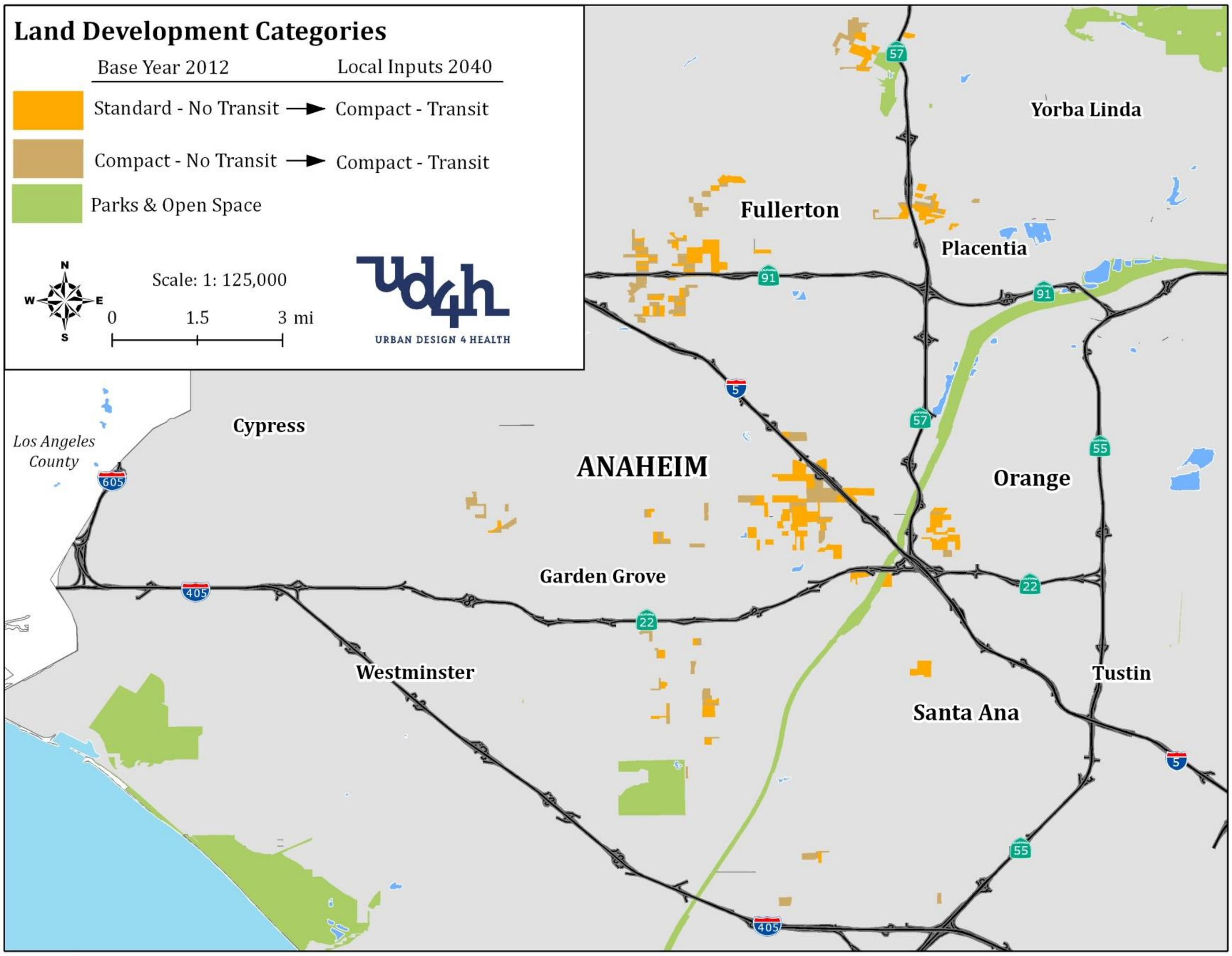


**Table 14. Comparison #1 - Population and Household Profile**

| | 2012<br>Urban Form: Compact<br>Transit: None | 2040<br>Urban Form: Compact<br>Transit: Yes |
|---|---|---|
| **# of Scenario Planning Zones (SPZs)** | 106 | 106 |
| **Total Population** | 20,943 | +5.7% |
| Children (<12 years) | 2,164 | +7.6% |
| Teens (12-17 years) | 2,316 | +6.2% |
| Adult (18-65 years) | 13,221 | +5.6% |
| Senior (>65 Years) | 1,699 | +1.3% |
| **Total Households** | 5,526 | +7.4% |

Notes: Base Year= 2012; Future Scenario = 2040

As previously noted, demographics were held equal between the base and future case (Table 15). On average, the demographic profile of the SPZs designated as **Compact, No Transit** tend to contain larger households (4.3 persons/household) with children, rented dwellings, a higher proportion of ethnic population, and lower education levels, than the county average of SPZ values (Table 15).

**Table 15. Comparison #1 – Demographics**

| Demographics | Orange County SPZs (2012)[a] | Comparison #1 SPZs (2012 & 2040)[a,b] |
|---|---|---|
| **Gender** | | |
| % Female | 50.6 | 51.2 |
| **Ethnicity** | | |
| % White, non-Hispanic | 44.2 | 25.2 |
| % Black or African American, non-Hispanic | 1.5 | 1.6 |
| % Asian | 17.8 | 18.3 |
| % American Indian or Alaska native, Native Hawaiian or Pacific islander, or Other | 3.1 | 2.5 |
| **Employment** | | |
| % Unemployed | 4.9 | 6.3 |
| **Education** | | |
| % High school diploma | 18.1 | 24.3 |
| % Some college, no degree or vocational/associate's degree | 28.6 | 27.7 |
| % Bachelor's degree | 23.3 | 13.6 |
| % Graduate degree | 12.5 | 5.4 |
| **Dwelling Tenure** | | |
| % Rent | 41.2 | 49.6 |
| **Vehicles per household** | 2.0 | 2.1 |
| **Household characteristics** | | |
| Household size | 3.0 | 4.3 |
| % of households with children <18 years old | 40.8 | 48.1 |
| **Annual Household Income** | | |
| % $10,000-$34,999 | 18.6 | 24.0 |
| % $35,000-$49,999 | 11.2 | 14.6 |
| % $50,000-$74,999 | 16.6 | 19.0 |
| % $75,000-$99,999 | 16.1 | 14.3 |
| % $100,000-$149,999 | 17.7 | 15.6 |
| % >$150,000 | 18.3 | 8.7 |

[a] Population-weighted mean

[b] Base Year= 2012; Future Scenario = 2040

Even though the LDC class for current and future conditions remained "Compact", the application of the Scenario 2040 changes did change the built environment in important ways. For example Scenario 2040 shows substantial increases in the future case for built environment measures capturing residential access (+48.6%), commercial access (+28.2%), retail/office FAR (+24.0%), and regional access (+23.7%).

Overall walkability for **Compact, Future Transit Only** SPZs increased by 24.2%. Distance to education and retail destinations decreased by about 20%, and the percentage of SPZs with access to rail within 1 km increased from 4.7% to 98.1% (Table 16).

**Table 16. Comparison #1 – Built Environment Measures**

| Built Environment Inputs | Orange County | 2012 Urban Form: Compact Transit: None | 2040 Urban Form: Compact Transit: Yes [a] |
|---|---|---|---|
| Intersection density (intersections/square mile) | 96.8 | 145.3 | **+10.1%** |
| Distance to nearest education (truncated at 2000m) | 147.8 | 155.4 | **-21.4%** |
| Distance to nearest retail (truncated at 2000m) | 84.7 | 50.6 | **-19.2%** |
| Distance to nearest park/open space | 422.0 | 514.9 | 0% |
| Distance to nearest transit (truncated at 2000m) | 499.7 | 261.2 | -0.1% |
| Retail/office floor-to-area ratio | 0.2 | 0.2 | **+24.0%** |
| Net residential density | 6.0 | 6.9 | **+18.3%** |
| Acreage of park space within 1km buffer | 117.8 | 32.4 | 0% |
| Count of transit stops/stations within 1km | 26.5 | 39.9 | 6.2% |
| Any rail within 1km (0=no, 1=yes) | 3.2% | 4.7% | **+1,980%**[6] |
| Dwelling unit accessibility | 836,904.7 | 738,744.2 | **+12.5%** |
| Employment accessibility | 1,308,865.4 | 1,058,948.2 | **+21.5%** |
| Mixed land use index | 0.5 | 0.4 | **+16.1%** |
| Residential access index | 0.2 | 0.7 | **+48.6%** |
| Commercial access index | 2.7 | 4.2 | **+28.2%** |
| Park access index | 0.9 | 0.1 | 0% |
| Regional access index | 1.4 | 1.5 | **+23.7%** |
| Transit access index | 0.5 | 1.6 | **+5.7%** |
| Major road exposure index | 1.8 | 2.3 | 0% |
| Walkability index (standard) | 1.9 | 3.6 | **+24.2%** |

***Future scenario key*** **Bold** Future scenario change > ± 5% — Future scenario % change (from 2012) in expected direction

[a] Percent change from base value

[6] Future value is 98.1% of SPZ have a transit stop or station (light rail, subway/metro, or heavy passenger rail)within 1km of their centroid.

Physical activity and health outcomes by age group are shown in Table 17. Future case outcome cells highlighted in blue indicate the predicted values are in the expected direction. Among children less than 12 years old, daily per capita recreation PA increased from 28.6 minutes to 33.5 minutes/day (+17.2%). Positive increases in minutes of walking per day (+12%) and the likelihood of walking to school (+6.9%) and were observed, while the odds of being obese dropped by 5.7%. Among teens aged 12-17 years, walking time increased from 17.6 minutes/day to 21.5 minutes/day (+21.9%), while the likelihood of walking to school rose by +18.1% from the base case value of 64.6%. The poor health proportion for teens decreased by 6.4%, under this land use development scenario.

**Table 17. Comparison #1 – Physical activity and health outcomes (children and teens)** [7]

| Outcomes | 2012 Urban Form: Compact Transit: None | 2040 Urban Form: Compact Transit: Yes |
|---|---|---|
| **Children (<12 years)** | | |
| CHTS Daily Per Capita Recreation PA (minutes/day) | 28.6 min | **17.2%** |
| CHTS Daily Per Capita Walking (minutes/day) | 16.2 min | **12.0%** |
| CHTS Daily Per Capita Auto (minutes/day) | 36.7 min | **-9.5%** |
| Days/week with > 60 minutes of physical activity | 4.1 | -0.5% |
| Likelihood of walking to school (%) | 57.3% | **6.9%** |
| BMI Percentile | 69.0 | -0.8% |
| Obese Population (%) | 36.2% | **-5.7%** |
| Poor Health Population (%) | 7.1% | +0.2% |
| **Teens (12-17 years)** | | |
| CHTS Daily Per Capita Recreation PA (minutes/day) | 27.0 min | 0.7% |
| CHTS Daily Per Capita Walking (minutes/day) | 17.6 min | **21.9%** |
| CHTS Daily Per Capita Auto (minutes/day) | 32.9 min | 2.4% |
| Days/week with > 60 minutes of physical activity | 3.3 | 0.4% |
| Likelihood of walking to school (%) | 64.6% | **18.1%** |
| BMI Percentile | 64.6 | -0.5% |
| Obese Population (%) | 18.6% | -3.6% |
| Poor Health Population (%) | 10.2% | **-6.4%** |

***Future scenario key*** **Bold** Future scenario change > ± 5% | Future scenario % change (from 2012) in expected direction

Physical activity and health outcome changes for adults and seniors were all in the expected direction under this land use change scenario (Table 6). Among adults, substantial gains in minutes of walking (+41.6%), biking (+33.1%) were observed, while daily minutes of driving decreased by 10.7%. The proportion of adults with type 2 diabetes decreased by nearly 5%, while poor health incidence was

[7] Reported results reflect population-weighted means.

lower by 12%. The proportion of obese adults remained nearly unchanged (-1.1%) between the base and future case under this land use change scenario.

Seniors showed slight improvements in future case health outcomes, with reductions in high blood pressure (-1.1%), heart disease (-2.8%), and type 2 diabetes (-2.8%). Notably, the obesity rate dropped by 17.6% in the future case scenario. Daily recreation PA and walking minutes increased slightly, while auto minutes dropped by 4.1%.

**Table 18. Comparison #1 – Physical activity and health outcomes (adults and seniors)** [8]

| Outcomes | 2012 Urban Form: Compact Transit: None | 2040 Urban Form: Compact Transit: Yes |
|---|---|---|
| **Adults (18-65 years)** | | |
| CHTS Daily Per Capita Recreation PA (minutes/day) | 13.4 min | **7.2%** |
| CHTS Daily Per Capita Walking (minutes/day) | 11.3 min | **41.6%** |
| CHTS Daily Per Capita Biking (minutes/day) | 1.4 min | **33.1%** |
| CHTS Daily Per Capita Auto (minutes/day) | 63.5 min | **-10.7%** |
| Obese Population (%) | 23.7% | -1.1% |
| Poor Health Population (%) | 21.6% | **-12.1%** |
| High Blood Pressure (%) | 18.4% | -1.4% |
| Heart Disease (%) | 3.6% | -0.1% |
| Diabetes - Type 2 (%) | 5.7% | -4.9% |
| **Seniors (>65 years)** | | |
| CHTS Daily Per Capita Recreation PA (minutes/day) | 12.7 min | 2.4% |
| CHTS Daily Per Capita Walking (minutes/day) | 10.1 min | 2.7% |
| CHTS Daily Per Capita Auto (minutes/day) | 51.0 min | -4.1% |
| Obese Population (%) | 22.8% | **-17.6%** |
| Poor Health Population (%) | 25.8% | -3.7% |
| High Blood Pressure (%) | 58.5% | -1.1% |
| Heart Disease (%) | 15.4% | -2.8% |
| Diabetes - Type 2 (%) | 18.4% | -2.8% |

***Future scenario key*** **Bold** Future scenario change > ± 5% | Future scenario % change (from 2012) in expected direction

Figure 12

shows the rate of adult obesity in the northern area of Orange County in 2012, with SPZs that had an unexpected change (increase) in the obesity rate in the future case (2040) highlighted using crosshatching. This map is presented as an example way to convey the information spatially; however, it

[8] Reported results reflect population-weighted means.

is acknowledged that the varying size, number, and spatial distribution of SPZs within a comparison presents challenges in displaying outcome data effectively in a static map format.

**Figure 12. Adult obesity rate (%), Orange County (2012).**
SPZs in the Compact, no transit --> Compact, Transit comparison are outlined in red.

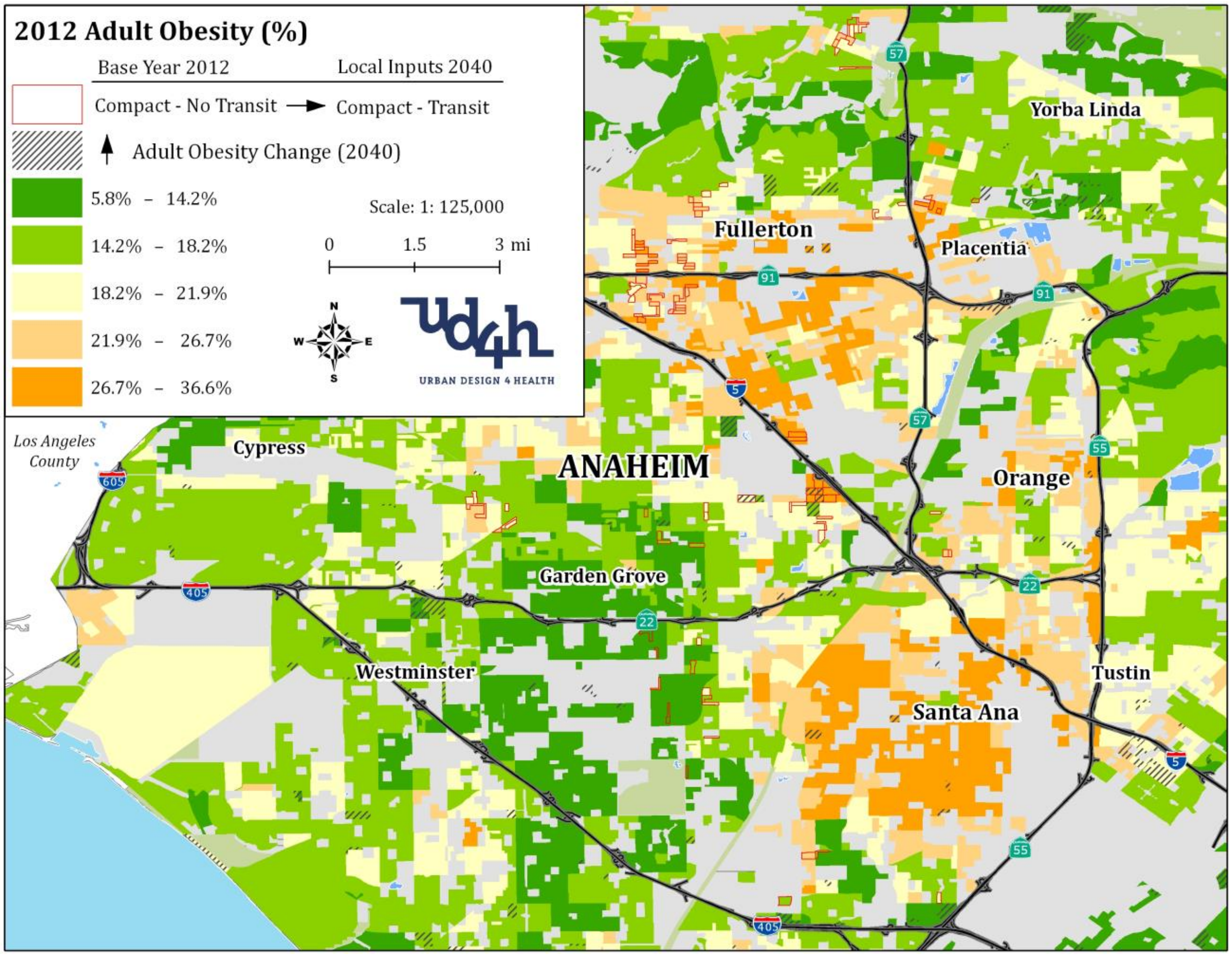
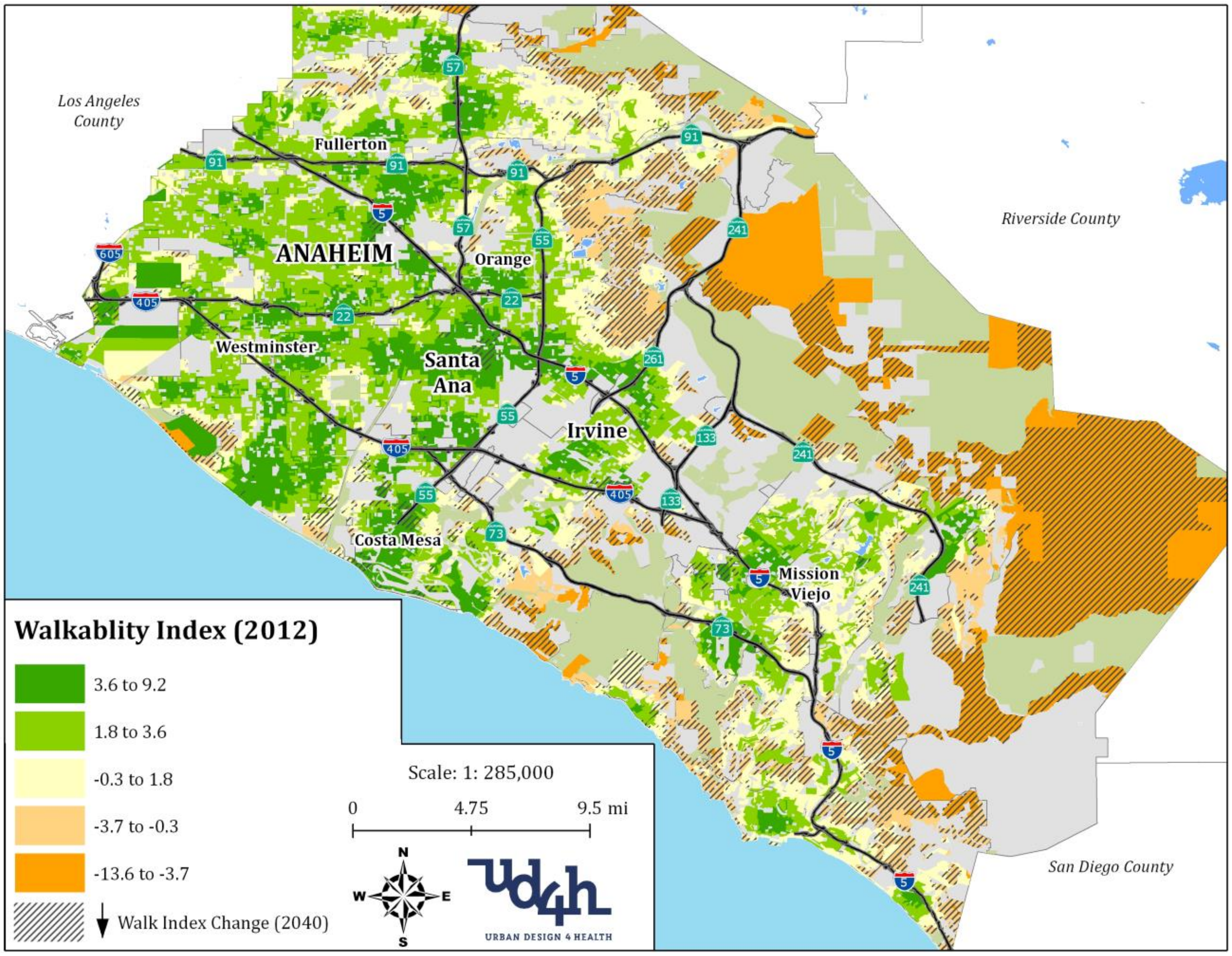



Figure 13 shows the variability in the walkability index values across Orange County.

**Figure 13. Orange County Walkability Index (2012), Scenario Planning Zones**




## *Summary of model results for five selected LDC comparisons*

The following section shows model results for the above LDC comparison plus four others, for base to future conditions. These five comparisons are identified in Table 13. The percentage change from the base to future case is shown for each of the five LDC comparisons for i) physical activity and health outcomes, and ii) built environment measure inputs.

***Note***: Comparisons of base to future conditions *within* a pair are based on the same geographic areas (SPZs) and population demographics. The only difference from base to future within these comparisons is the built environment. However, caution should be used when making comparisons *between* pairs in Table 19 through Table 21 below, as results for each pair are based on their own unique geographic areas (SPZs) and population demographics.

### *Children and Teens*

Among children less than 12 years, areas with compact land development and high density transit in the future case showed the most positive change in minutes per day of recreation PA (17%). The **Compact, Future Transit Only** comparison, based on the population living there and its specific geographic area, had the greatest reduction in auto minutes per day (-9.5%), while the **Standard to Urban, no Transit** comparison had the greatest change, for its population and geographic area, in minutes of walking per day (+17.6%) of the five comparisons. The **Standard to Urban, Future Transit Only** comparison had the greatest change in likelihood of walking to school (+8%), and reduction in obesity (-9.9%) of the five comparisons (Table 19).

For teens, the **Compact, Future Transit Only** comparison had a large increase in walking minutes per day (+21.9%) and likelihood of walking to school (+18.1%). The **Standard to Urban, No Transit** comparison also showed a substantial increase in minutes of walking per day (+20.7%). Obesity and poor health outcomes decreased the most under the **Standard to Urban, Future Transit Only** comparison based on population and SPZ characteristics, although all five comparisons shown below had a reduction in incidence in these outcomes (Table 19). Changes in daily recreation PA ands days with >60 minutes of physical activity were negligible for all five comparison for the teen cohort.

**Table 19. Base *versus* future summary for five LDC comparisons - physical activity and health outcomes (children and teens)** [9]

| Outcomes | (1) Compact. Transit: future only | (2) Standard to compact. Transit: future only | (3) Standard to urban. Transit: none | (4) Standard to urban Transit: future only | (5) Standard to compact. Transit: none |
|---|---|---|---|---|---|
| **Children (<12 years)** | | | | | |
| CHTS Daily Per Capita Recreation PA (minutes/day) | **+17.2%** | **17.8%** | **13.6%** | **5.5%** | 4.2% |
| CHTS Daily Per Capita Walking (minutes/day) | **+12.0%** | 4.9% | **17.6%** | 0% | **-13.2%** |
| CHTS Daily Per Capita Auto (minutes/day) | **-9.5%** | **-7.2%** | **-7.8%** | 2.0% | **5.9%** |
| Days/week with > 60 minutes of physical activity | -0.5% | -1.1% | -1.1% | -3.1% | -0.4% |
| Likelihood of walking to school (%) | **+6.9%** | 3.0% | 4.8% | **8.0%** | -0.3% |
| BMI Percentile | -0.8% | -0.8% | -0.9% | -1.2% | -0.6% |
| Obese Population (%) | **-5.7%** | **-6.2%** | -4.4% | **-9.9%** | **-8.9%** |
| Poor Health Population (%) | +0.2% | 0.5% | 0.4% | 1.7% | 0.2% |
| **Teens (12-17 years)** | | | | | |
| CHTS Daily Per Capita Recreation PA (minutes/day) | 0.7% | -0.9% | -1.6% | 0.2% | -1.3% |
| CHTS Daily Per Capita Walking (minutes/day) | **21.9%** | **14.8%** | **20.7%** | **14.4%** | **-8.4%** |
| CHTS Daily Per Capita Auto (minutes/day) | 2.4% | **6.9%** | 2.3% | 1.0% | **6.4%** |
| Days/week with > 60 minutes of physical activity | 0.4% | -0.9% | -1.1% | -2.5% | -0.5% |
| Likelihood of walking to school (%) | **18.1%** | **16.2%** | **13.7%** | **12.1%** | 3.5% |
| BMI Percentile | -0.5% | -0.8% | 0% | -1.1% | -1.8% |
| Obese Population (%) | -3.6% | -3.0% | -2.7% | **-6.9%** | -1.6% |
| Poor Health Population (%) | **-6.4%** | **-6.9%** | -2.0% | **-12.2%** | **-10.5%** |

***Future scenario key*** **Bold** Future scenario change > ± 5% [shaded] Future scenario % change (from 2012) in expected direction

[9] Reported results reflect population-weighted means.

### *Adults and Seniors*

Land development change that included **high density transit** resulted in a substantial increase in minutes of walking per day among adults in the range of 36-50% (Table 20). Time spent biking also increased by about 30% for these LDC comparisons (taking into account unique population and SPZ characteristics for each pair), while the comparisons without high density transit had much lower increase in minutes spent walking and cycling. Comparisons with the addition of high density transit in the future case also had the greatest reduction in the percentage of adults with poor health among the five comparisons.

Among seniors, the **Standard to Urban, Future Transit Only** comparison showed very positive change in physical activity outcomes among seniors, with a 31.5% increase in walking minutes per day and an 8.3% decrease in auto minutes per day (Table 20). The **Standard to Urban, no Transit** comparison also had a substantial increase in minutes of walking per day (+23.1%), and reduction in auto minutes per day (-7.4%). The proportion of obese seniors decreased under all five comparisons, with **Compact, Future Transit Only** and **Standard to Compact, Future Transit Only** showing the largest reduction in obesity of 17.6% and 18.5% respectively, based on the population and SPZ characteristics of these land use comparisons.

**Table 20. Base *versus* future summary for five LDC comparisons - physical activity and health outcomes (adults and seniors)** [10]

| Outcomes | (1) Compact. Transit: future only | (2) Standard to compact. Transit: future only | (3) Standard to urban. Transit: none | (4) Standard to urban Transit: future only | (5) Standard to compact. Transit: none |
|---|---|---|---|---|---|
| **Adults (18-65 years)** | | | | | |
| CHTS Daily Per Capita Recreation PA (minutes/day) | **7.2%** | **7.0%** | 0.4% | 3.0% | 3.1% |
| CHTS Daily Per Capita Walking (minutes/day) | **41.6%** | **35.9%** | **21.6%** | **49.4%** | -1.9% |
| CHTS Daily Per Capita Biking (minutes/day) | **33.1%** | **28.4%** | **8.2%** | **29.3%** | -3.6% |
| CHTS Daily Per Capita Auto (minutes/day) | **-10.7%** | **-9.8%** | -4.3% | **-10.4%** | 0.7% |
| Obese Population (%) | -1.1% | -2.0% | -2.5% | -3.8% | -1.6% |
| Poor Health Population (%) | **-12.1%** | **-12.2%** | -4.7% | **-5.5%** | -3.8% |
| High Blood Pressure (%) | -1.4% | -1.0% | -0.8% | -1.7% | -0.8% |
| Heart Disease (%) | -0.1% | -0.2% | -0.2% | -0.3% | -0.2% |
| Diabetes - Type 2 (%) | -4.9% | -4.3% | 0.6% | 1.4% | **-5.2%** |
| **Seniors (>65 years)** | | | | | |
| CHTS Daily Per Capita Recreation PA (minutes/day) | 2.4% | 4.6% | -1.0% | **6.2%** | **10%** |
| CHTS Daily Per Capita Walking (minutes/day) | 2.7% | -2.8% | **23.1%** | **31.5%** | **-7.4%** |
| CHTS Daily Per Capita Auto (minutes/day) | -4.1% | -4.6% | **-7.4%** | **-8.3%** | 2.8% |
| Obese Population (%) | **-17.6%** | **-18.5%** | **-11.4%** | **-9.8%** | **-5.2%** |
| Poor Health Population (%) | -3.7% | -3.5% | 1.5% | 2.6% | -2.5% |
| High Blood Pressure (%) | -1.1% | -1.2% | -0.4% | -1.0% | -0.4% |
| Heart Disease (%) | -2.8% | -3.6% | -1.1% | -1.9% | -2.2% |
| Diabetes - Type 2 (%) | -2.8% | -2.0% | 0.1% | 3.9% | -0.9% |

***Future scenario key*** **Bold** Future scenario change > ± 5% — Future scenario % change (from 2012) in expected direction

## Built Environment Inputs

The **Standard to Urban, Future Transit Only** comparison showed the largest percentage increase in built environment inputs measuring connectivity, land use mix, density, accessibility, and transit. In terms of overall walkability, the **Standard to Urban, no Future Transit** comparison had a large increase from base

[10] Reported results reflect population-weighted means.

to future case (+53.9%), as did the **Standard to Compact, Future Transit Only** (+41.6%). Regional accessibility increased by about 25% for each comparison; change in variables measuring dwelling unit and employment accessibility were also consistent across each LDC comparison with increases in the range of 12-15% and 21-24% respectively.

**Table 21. Base *versus* future summary for five LDC comparisons – built environments inputs**

| Built environment inputs | (1) Compact. Transit: future only | (2) Standard to compact. Transit: future only | (3) Standard to urban. Transit: none | (4) Standard to urban Transit: future only | (5) Standard to compact. Transit: none |
|---|---|---|---|---|---|
| Intersection density (intersections per square mile) | **10.1%** | **51.6%** | **30.7%** | **154.5%** | **22.4%** |
| Distance to nearest education (truncated at 2000m) | **-21.4%** | **-8.6%** | **-100%** | 0% | **-44.0%** |
| Distance to nearest retail (truncated at 2000m) | **-19.2%** | **-21.1%** | **-100%** | **-69.8%** | **-46.1%** |
| Distance to nearest restaurant (truncated at 2000m) | **-11.5%** | **-14.8%** | **-100%** | **-60.3%** | **-56.6%** |
| Distance to nearest park/open space | 0% | 0% | 0% | 0% | 0% |
| Distance to nearest transit (truncated at 2000m) | -0.1% | -3.3% | 0% | 0% | 0% |
| Retail/office floor-to-area ratio | **24.0%** | **23.2%** | **15.9%** | **152.1%** | **19.1%** |
| Net residential density | **18.3%** | **21.7%** | **31.0%** | **191.4%** | -1.1% |
| Acreage of park space within 1km buffer | 0% | 0% | 0% | 0% | 0% |
| Count of transit stops/stations within 1km | **6.2%** | 9.1% | 0.7% | **69.0%** | 3.6% |
| Any rail within 1km (0=no, 1=yes) | **1980%** | **1577.8%** | 0% | **33.3%** | **66.7%** |
| Dwelling unit accessibility | **12.5%** | **13.1%** | **13.7%** | **14.4%** | **14.4%** |
| Employment accessibility | **21.5%** | **22.3%** | **23.2%** | **23.3%** | **23.4%** |
| Mixed land use index | **16.1%** | **15.1%** | 4.7% | -2.4% | **15.0%** |
| Residential access index | **48.6%** | **58.5%** | **134.6%** | **-588.6%** | 3.0% |
| Commercial access index | **28.2%** | **27.0%** | **23.1%** | **83.8%** | **20.1%** |
| Park access index | 0% | 0% | 0% | 0% | 0% |
| Regional access index | **23.7%** | **23.6%** | **24.2%** | **24.4%** | **31.2%** |
| Transit access index | **5.7%** | **8.5%** | 0.6% | **49.1%** | 3.0% |
| Major road exposure index | 0% | 0% | 0% | 0% | 0% |
| Walkability index (standard) | **24.2%** | **41.6%** | **53.9%** | **383.9%** | **18.6%** |

***Future scenario key*** **Bold** Future scenario change > ± 5% Future scenario % change (from 2012) in expected direction

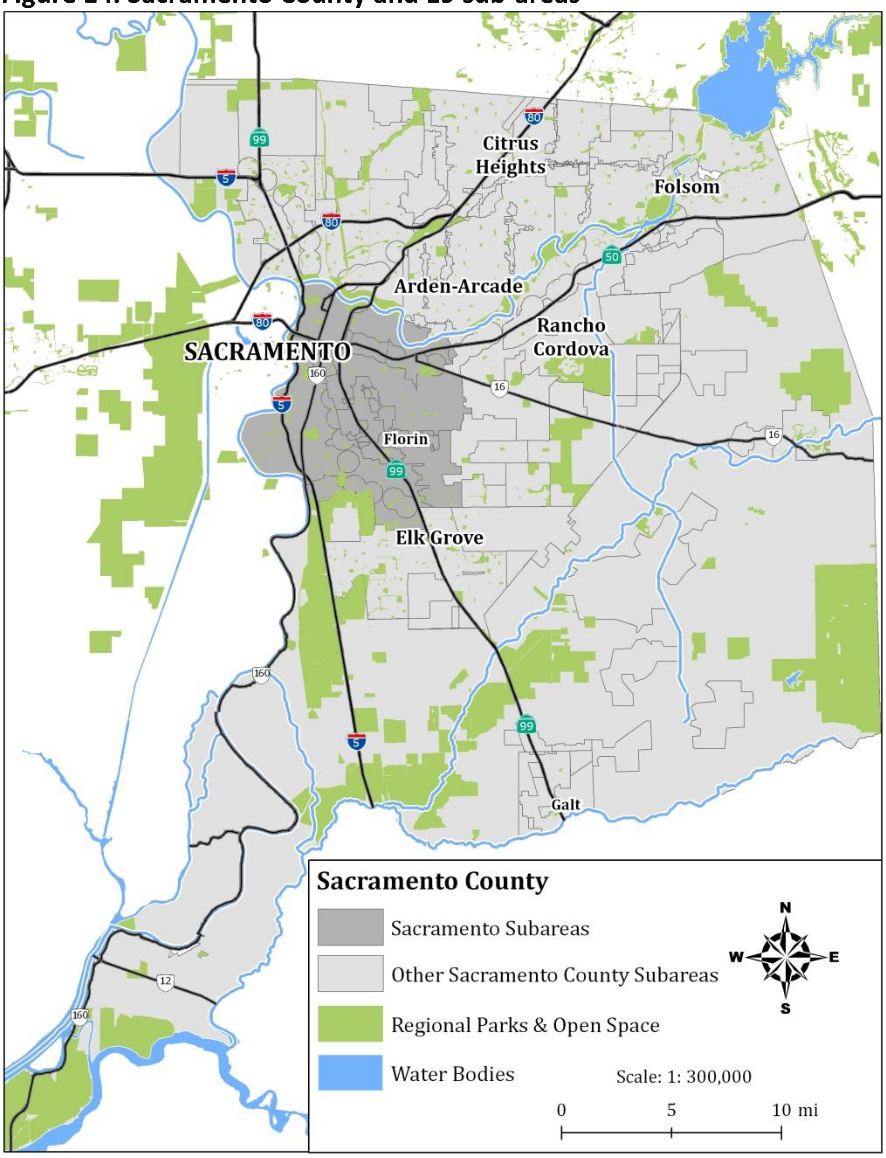
## Pilot #2 - Sacramento County

### Background

Nineteen sub-areas from Sacramento County were selected by the Sacramento Area Council of Governments (SACOG) to highlight built environment, physical activity, and health outcomes calculated by the Public Health Module for base case and future scenario time points. Using a 150m grid cell surface created for the county, built environment measure values were calculated for each cell and then aggregated to the sub-area and county levels.

Figure 14 shows the Sacramento region and nineteen sub-areas highlighted in dark gray. The selected sub-areas are contiguous, but vary in size and population.

**Figure 14. Sacramento County and 19 sub-areas**



## Comparison Methodology

Physical activity and health outcomes were modelled for the nineteen sub-areas for two time points:

- Base Case (2012), and
- Future Scenario (2036)

Models for base case outcomes used 2012 demographics and built environment conditions, while models for future scenario outcomes used 2012 demographics and 2036 built environment conditions.

Sub-area and county-level physical activity and health outcomes for 2012 and 2036 are population-weighted (2012) aggregations of grid-level values, with results shown only for populated grids in 2012. County level built environment inputs are (2012) unweighted averages of grid-level values.

Results from the Public Health Module were produced at the 150m grid level by age using the following population cohorts:

- Adults (18 – 64 years)
- Seniors ( > 65 years)
- Teens ( 12 – 18 years)
- Children (< 12 years)

Grid level model results were then aggregated from to sub-area and county means based on a population-weighted formula. Built environment inputs for the base case time point are listed in Table 22.

for the nineteen sub-areas. The downtown Sacramento sub-areas located east and west of 16th Street had the highest overall walkability (7.7 and 6.9 respectively), while the Delta Shores had the lowest walkability of the nineteen sub-areas (-3.7).

**Table 22. Sample of Built Environment 2012 Inputs**
*(Non-weighted mean values of 150m grids within each sub-area.)*

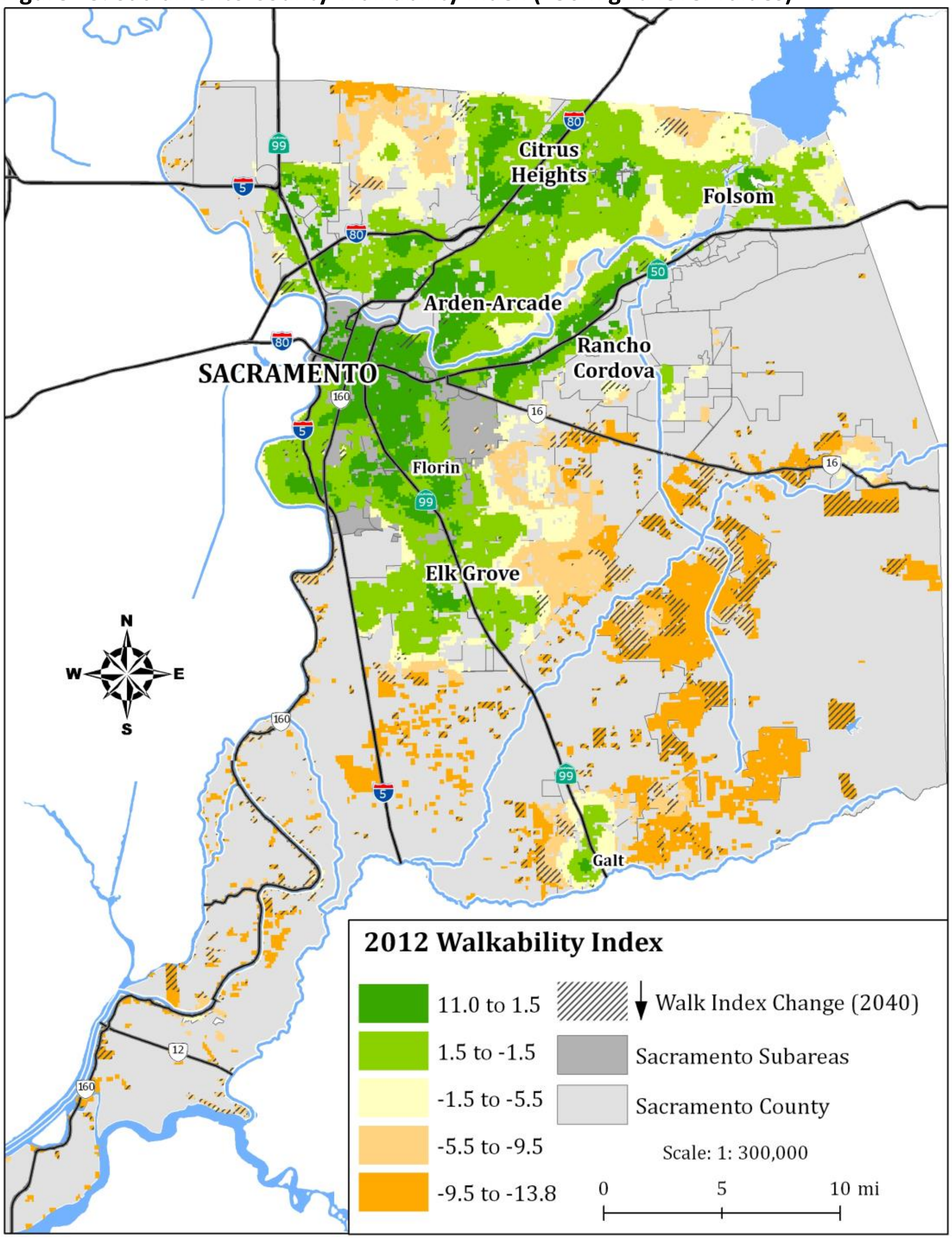
| | Walkability index (standard) | | | | | | |
|---|---|---|---|---|---|---|---|
| Sub Area | Walkability index (standard) | Residential access index | Commercial access index | Network connectivity index | Mixed Use (5) | Transit access index | Net residential density (units/(res & mixed acre) |
| Sac City- Corridor- Downtown Sacramento (East of 16th St) | **7.7** | **2.3** | **5.4** | **4.4** | **0.5** | **4.7** | **26.4** |
| Sac City- Corridor- Downtown Sacramento (West of 16th St) | **6.9** | **2.3** | **7.1** | **2.7** | **0.6** | **9.6** | **39.5** |
| Sac City- Corridor- Franklin Blvd 1 | 1.6 | 0.3 | 1.8 | 0.7 | 0.3 | 2.3 | 7.8 |
| Sac City- Corridor- Gold Line Seg 1 (39th to 59th) | 3.6 | 0.7 | 2.8 | 2.2 | 0.4 | 3.9 | 9.7 |
| Sac City- Corridor- Gold Line Seg 2 (65th to Power Inn) | 1.3 | 0.5 | 2.5 | -0.4 | 0.5 | 1.9 | 10.9 |
| Sac City- Corridor- Gold Line Seg 3 (College Greens and part of watt) | 0.6 | 0.3 | 1.2 | -0.7 | 0.4 | 2.0 | 9.0 |
| Sac City- Corridor- South Line Seg 1 (Broadway to 47th) | 2.6 | 0.5 | 1.3 | 1.8 | 0.3 | 2.2 | 9.3 |
| Sac City- Corridor- South Line Seg 2 (Florin) | 1.9 | 0.5 | 2.4 | 0.5 | 0.4 | 1.5 | 8.9 |
| Sac City- Corridor- South Line Seg 3 (Meadowview to CRC) | **-0.1** | 0.4 | **-1.6** | 0.0 | **0.2** | 1.0 | 8.2 |
| Sac City- Corridor- Stockton Blvd 1 (14th Ave to Florin Rd) | 2.0 | 0.8 | 2.3 | 0.4 | 0.3 | 1.8 | 9.2 |
| Sac City- Developing- Delta Shores Specific Plan | **-3.7** | **-1.7** | **-0.1** | **-3.1** | 0.4 | **-2.0** | **6.0** |
| Sac City- Established-CH, Orangevale, AA, Carm, FO | 1.2 | 1.2 | 2.6 | **-1.3** | 0.4 | 1.0 | 14.1 |
| Sac City- Established-Downtown/East Sac | 1.9 | 0.6 | 1.7 | 0.7 | 0.3 | 2.5 | 9.7 |
| Sac City- Established-South Sacramento | 1.6 | **0.2** | 0.9 | 1.0 | 0.3 | 1.6 | 8.0 |
| Sac County- Corridor- Florin Rd | 0.7 | **0.2** | 2.4 | -0.8 | 0.4 | 0.7 | 8.3 |
| Sac County- Corridor- Franklin Blvd 2 | 1.1 | 0.7 | 1.0 | -0.2 | 0.3 | 1.5 | 10.4 |
| Sac County- Corridor- Stockton Blvd 1 (14th Ave to Florin Rd) | 2.3 | 0.8 | 2.4 | 0.8 | 0.4 | 1.8 | 9.1 |
| Sac County- Corridor- Stockton Blvd 2 (Florin Rd to Mack Rd) | 0.9 | 0.3 | 1.9 | -0.2 | 0.3 | 1.1 | 7.9 |
| Sac County- Established- South Sacramento | 0.6 | 0.3 | 0.0 | 0.4 | **0.2** | **0.1** | **7.4** |

Two highest column values

Two lowest column values

Walkability index values using 2012 built environment inputs are mapped in Figure 15. The majority of grid cells are in the top two categories of walkability (green). While most grids increase in walkability between 2012 and 2036, grids with cross-hatching indicate a decrease in walkability at the 2036 time point.

**Figure 15. Sacramento County Walkability Index (150m grid level values)**



## Results

### *Sub-area Level*

Changes in physical activity and health outcomes between 2012 and 2036 are shown in Table 23 for the nineteen sub-areas. Values for each outcome are the non-weighted mean, stratified by age group. Among adults, time spent walking and biking for transportation increased in the future case for all nineteen sub-areas by an average of +7.7% and +7.2% respectively. The proportion of adults with type 2 diabetes decreased for nearly all sub-areas by an average of 1.6%, while incidence of obesity decreased in all nineteen sub-areas by an average of 2.1%. Walking for transportation among seniors rose by an average of +7.2% in the future case among the nineteen sub-areas, while the proportion of obese seniors decreased by a mean value of 2.0%.

Positive change in physical activity among children was observed for outcomes predicting time spent walking for transportation (+6.8%) and likelihood of walking school (+2.7%) across all nineteen sub-areas. The percentage of children with body weights classified as obese declined by an average of 3.6% across all sub-areas.

An increase in time spent walking for transportation (+4.6%) and likelihood of walking to school (+1.7%) was also observed for the teen cohort, although time spent engaging in recreational PA decreased in all nineteen sub-areas by an average of 2.6%.

**Table 23. Sacramento County outcome changes at sub-area level from 2012 to 2036**
(Non-weighted mean of 19 sub-areas. Sub-area values are population weighted averages of grid level values.)

| Age Cohort | Outcome | At the sub-area level (n=19) % diff from 2012. ((2036-2012)/2012) Mean | Min | Max | # of sub-areas with positive change in 2036 | # sub-areas with negative change in 2036 |
|---|---|---|---|---|---|---|
| Adults 19-65 years | Transportation biking (minutes) | **7.2%** | **5.5%** | **10.0%** | 19 | 0 |
| | Recreational PA (minutes) | -0.3% | -0.7% | -0.03% | 0 | 19 |
| | Transportation walking (minutes) | **7.7%** | 4.7% | **15.5%** | 19 | 0 |
| | Type 2 diabetes (%) | -1.6% | -2.5% | 0.2% | 2 | 17 |
| | Poor general health (%) | 0.1% | -0.2% | 0.5% | 12 | 7 |
| | Heart disease (%) | -0.2% | -0.2% | -0.1% | 0 | 19 |
| | High blood pressure (%) | -0.6% | -1.0% | -0.5% | 0 | 19 |
| | Obese (%) | -2.1% | -2.7% | -1.7% | 0 | 19 |
| Seniors >65 years | Recreational PA (any) | 1.6% | 1.3% | 2.8% | 19 | 0 |
| | Transportation walking (minutes) | **7.2%** | 4.7% | **13.2%** | 19 | 0 |
| | Type 2 diabetes (%) | -0.6% | -1.4% | 1.7% | 4 | 15 |
| | Poor general health (%) | 1.0% | 0.4% | 1.8% | 19 | 0 |
| | Heart disease (%) | -1.2% | -1.3% | -1.0% | 0 | 19 |
| | High blood pressure (%) | 0.1% | 0.1% | 0.1% | 19 | 0 |
| | Obese (%) | -2.0% | -2.2% | -1.5% | 0 | 19 |
| Children <12 years | BMI percentile | -0.7% | -1.4% | -0.5% | 0 | 19 |
| | Poor general health (%) | 0.2% | 0.02% | 0.7% | 19 | 0 |
| | Obese (%) | -3.5% | -6.2% | -2.4% | 0 | 19 |
| | Recreational PA (minutes) | 0.1% | 0.1% | 0.6% | 19 | 0 |
| | Transportation walking (minutes) | **6.8%** | 4.4% | **10.8%** | 19 | 0 |
| | Likelihood of walking to school (%) | 2.7% | 0.7% | **8.4%** | 19 | 0 |
| Teenagers 12-18 years | BMI percentile | -0.03% | -0.3% | -0.001% | 0 | 19 |
| | Poor general health (%) | 0.7% | -4.5% | 2.3% | 15 | 4 |
| | Obese (%) | -1.3% | -4.0% | -0.4% | 0 | 19 |
| | Recreational PA (minutes) | -2.6% | -2.9% | -2.3% | 0 | 19 |
| | Transportation walking (minutes) | 4.6% | 2.5% | **9.3%** | 19 | 0 |
| | Likelihood of walking to school (%) | 1.7% | 0.5% | **6.8%** | 19 | 0 |

**Future Scenario Key** | **Bold** Future scenario change > ± 5% | Future scenario % change (from 2012) in expected direction

Figure 17 shows the percentage of obese adults in Sacramento County (2012), and Figure 16 shows the spatial variation in the likelihood of children walking to school, calculated at the 150m grid cell level.

**Figure 17: Adult obesity rate (%), Sacramento County (2012)**

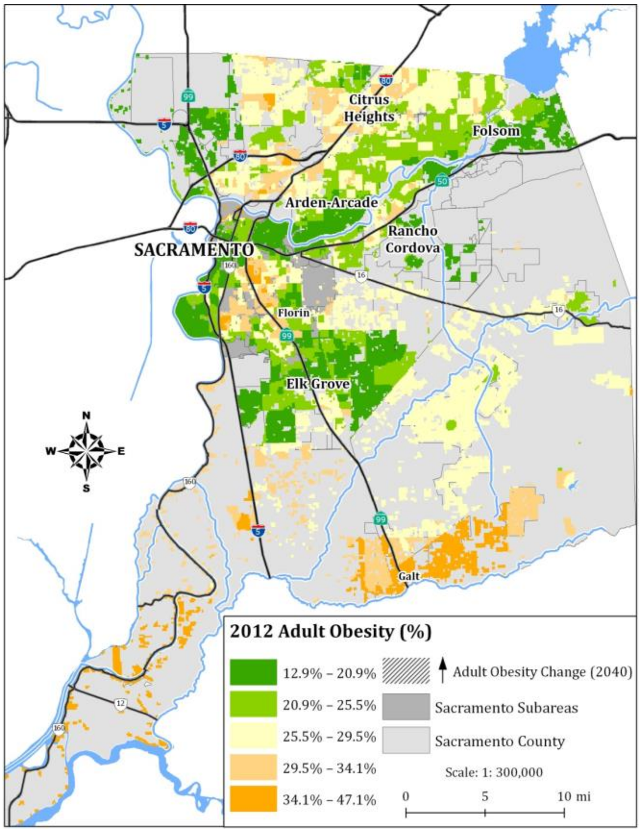



**Figure 16: Likelihood of child walking to school (%), Sacramento County (2012)**

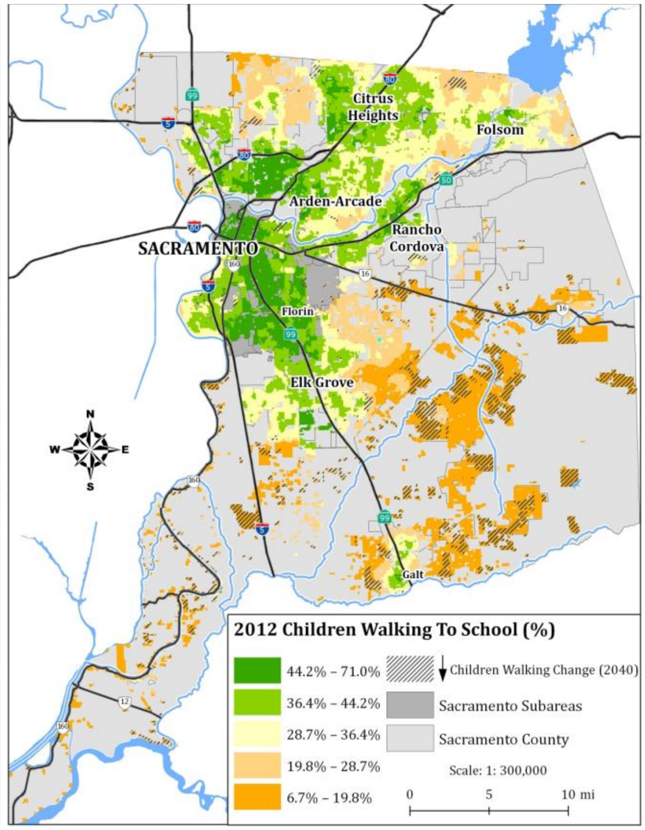



Table 24 and Table 25 expand on the sub-area level results shown in Table 23 by showing mean physical activity and health outcomes for adults aged 19-65 years for each of the nineteen sub-areas. The downtown Sacramento sub-areas east and west of 16th St. had the largest increase in time spent biking (+9.1% and +10% respectively) in the future time point. These sub-areas also had large increases in time spent walking (+6.2 and 9.4% respectively). The Delta Shores sub-area had the largest change in time spent walking in the future case (+15.5%), followed by Sacramento-City-Corridor-Gold Line Seg 3 (+9.3%).

Change in obesity levels ranged from -1.7% to -2.7%, with the great decrease in the Delta Shores and Sacramento City-Corridor-Gold Line Seg 2 sub-areas (-2.7%). Reduction in the percentage of adults with high blood pressure ranged from 0.5% to 1.0%; the Downtown Sacramento sub-area west of 16th street showed the largest decrease for this outcome (-1.0%).

**Table 24. Mean Physical Activity Outcomes in 2012 and 2036 (Grid-Based) at the Sacramento County Sub-area Level (adults 19-65 yrs)** [a]

| Sub-Area | | Population | CHTS Daily Per Capita Recreation PA (min/day) | CHTS Daily Per Capita Walking (min/day) | CHTS Daily Per Capita Biking (min/day) | CHTS Daily Per Capita Auto (min/day) |
|---|---|---|---|---|---|---|
| Sac City- Corridor- Downtown Sacramento (East of 16th St) | Base | 19,963 | 15.8 | 25.7 | 3.0 | 49.3 |
| | % Change | **18.9%** | -0.1% | **6.2%** | **9.1%** | -0.4% |
| Sac City- Corridor- Downtown Sacramento (West of 16th St) | Base | 16,299 | 13.9 | 43.9 | 4.6 | 40.4 |
| | % Change | **42.7%** | -0.5% | **9.4%** | **10.0%** | -2.4% |
| Sac City- Corridor- Franklin Blvd 1 | Base | 6,652 | 11.9 | 10.5 | 1.2 | 55.4 |
| | % Change | **14.9%** | -0.2% | **7.3%** | **7.4%** | 0.1% |
| Sac City- Corridor- Gold Line Seg 1 (39th to 59th) | Base | 8,331 | 19.6 | 12.6 | 2.3 | 61.1 |
| | % Change | 4.2% | -0.1% | **5.4%** | **7.1%** | 0.6% |
| Sac City- Corridor- Gold Line Seg 2 (65th to Power Inn) | Base | 6,310 | 16.8 | 12.4 | 2.1 | 58.2 |
| | % Change | **25.1%** | -0.7% | **12.5%** | **8.7%** | -0.9% |
| Sac City- Corridor- Gold Line Seg 3 (College Greens and part of watt) | Base | 3,069 | 18.4 | 10.5 | 2.2 | 61.9 |
| | % Change | **8.1%** | -0.4% | **9.3%** | **8.0%** | -0.2% |
| Sac City- Corridor- South Line Seg 1 (Broadway to 47th) | Base | 14,696 | 17.0 | 12.5 | 2.0 | 58.7 |
| | % Change | **9.1%** | -0.2% | **6.5%** | **7.1%** | 0.2% |
| Sac City- Corridor- South Line Seg 2 (Florin) | Base | 6,238 | 10.9 | 13.5 | 1.1 | 51.8 |
| | % Change | **30.8%** | -0.5% | **9.6%** | **7.2%** | -0.8% |
| Sac City- Corridor- South Line Seg 3 (Meadowview to CRC) | Base | 27,569 | 13.3 | 6.3 | 0.7 | 65.4 |
| | % Change | **15.4%** | -0.2% | **6.6%** | **5.9%** | 0.2% |
| Sac City- Corridor- Stockton Blvd 1 (14th Ave to Florin Rd) | Base | 8,545 | 10.0 | 8.2 | 0.8 | 58.9 |
| | % Change | **21.0%** | 0.0% | 4.9% | **6.6%** | 0.6% |
| Sac City- Developing- Delta Shores Specific Plan | Base | 528 | 11.9 | 6.3 | 0.9 | 66.3 |
| | % Change | **75.2%** | -0.7% | **15.5%** | **7.3%** | -1.6% |
| Sac City- Established-CH, Orangevale, AA, Carm, FO | Base | 5,773 | 18.7 | 10.9 | 2.3 | 64.7 |
| | % Change | 0.7% | -0.3% | **5.0%** | **5.5%** | 0.9% |
| Sac City- Established-Downtown/East Sac | Base | 25432 | 18.8 | 13.2 | 2.4 | 62.0 |
| | % Change | 4.2% | -0.3% | **7.2%** | **6.7%** | 0.5% |
| Sac City- Established-South Sacramento | Base | 194,379 | 14.0 | 7.4 | 0.9 | 65.4 |
| | % Change | **5.2%** | -0.1% | **5.4%** | **6.5%** | 0.5% |
| Sac County- Corridor- Florin Rd | Base | 6,535 | 11.2 | 10.3 | 0.9 | 60.6 |
| | % Change | **12.3%** | -0.1% | 4.7% | **6.4%** | 0.5% |
| Sac County- Corridor- Franklin Blvd 2 | Base | 7,981 | 11.8 | 11.4 | 1.1 | 58.5 |
| | % Change | **20.1%** | -0.4% | **9.3%** | **7.7%** | -0.3% |
| Sac County- Corridor- Stockton Blvd 1 (14th Ave to Florin Rd) | Base | 2,823 | 9.9 | 10.5 | 0.9 | 58.2 |
| | % Change | **22.5%** | -0.2% | **6.2%** | **7.1%** | 0.3% |
| Sac County- Corridor- Stockton Blvd 2 (Florin Rd to Mack Rd) | Base | 10,865 | 11.9 | 6.1 | 0.6 | 65.3 |
| | % Change | **27.9%** | -0.4% | **7.9%** | **6.6%** | 0.0% |
| Sac County- Established-South Sacramento | Base | 79,710 | 12.4 | 5.8 | 0.7 | 66.8 |
| | % Change | **8.1%** | -0.2% | **6.5%** | **6.6%** | 0.3% |

***Future Scenario Key*** **Bold** Future scenario change > ± 5% | [shaded] Future scenario % change (from 2012) in expected direction

[a] Percent change from base value

**Table 25. Mean Health Outcomes in 2012 and 2036 (Grid-Based) at the Sacramento County Sub-area Level (adults 19-65 yrs) [a]**

| Sub-Area | | Obese Population (%) | Poor Health Population (%) | High Blood Pressure (%) | Heart Disease (%) | Diabetes - Type 2 (%) |
|---|---|---|---|---|---|---|
| Sac City- Corridor- Downtown Sacramento (East of 16th St) | Base | 22.9% | 17.1% | 18.8% | 4.4% | 4.2% |
| | % Change | -1.9% | 0.0% | -0.9% | -0.2% | -2.1% |
| Sac City- Corridor- Downtown Sacramento (West of 16th St) | Base | 25.9% | 35.0% | 21.6% | 6.1% | 6.0% |
| | % Change | -2.4% | 0.5% | -1.0% | -0.2% | 0.1% |
| Sac City- Corridor- Franklin Blvd 1 | Base | 30.3% | 39.4% | 27.3% | 6.6% | 8.5% |
| | % Change | -2.0% | 0.0% | -0.6% | -0.2% | -2.0% |
| Sac City- Corridor- Gold Line Seg 1 (39th to 59th) | Base | 21.0% | 8.1% | 19.4% | 4.5% | 4.0% |
| | % Change | -2.2% | -0.1% | -0.6% | -0.2% | -2.5% |
| Sac City- Corridor- Gold Line Seg 2 (65th to Power Inn) | Base | 22.7% | 13.8% | 16.3% | 3.4% | 3.1% |
| | % Change | -2.7% | 0.5% | -0.8% | -0.2% | -0.9% |
| Sac City- Corridor- Gold Line Seg 3 (College Greens and part of watt) | Base | 23.0% | 10.3% | 21.5% | 4.9% | 4.3% |
| | % Change | -2.4% | 0.3% | -0.7% | -0.2% | -1.5% |
| Sac City- Corridor- South Line Seg 1 (Broadway to 47th) | Base | 23.1% | 17.3% | 23.5% | 5.5% | 5.7% |
| | % Change | -2.1% | 0.1% | -0.6% | -0.2% | -1.8% |
| Sac City- Corridor- South Line Seg 2 (Florin) | Base | 29.5% | 46.7% | 31.6% | 7.7% | 9.2% |
| | % Change | -2.0% | 0.3% | -0.6% | -0.2% | -0.7% |
| Sac City- Corridor- South Line Seg 3 (Meadowview to CRC) | Base | 24.7% | 27.2% | 25.4% | 4.9% | 6.5% |
| | % Change | -1.7% | 0.1% | -0.5% | -0.1% | -1.6% |
| Sac City- Corridor- Stockton Blvd 1 (14th Ave to Florin Rd) | Base | 25.5% | 47.4% | 27.5% | 6.7% | 8.3% |
| | % Change | -1.9% | -0.2% | -0.5% | -0.2% | -2.4% |
| Sac City- Developing- Delta Shores Specific Plan | Base | 25.0% | 36.8% | 24.8% | 5.1% | 5.7% |
| | % Change | -2.7% | 0.4% | -0.9% | -0.2% | 0.2% |
| Sac City- Established-CH, Orangevale, AA, Carm, FO | Base | 18.5% | 9.3% | 15.6% | 3.3% | 2.6% |
| | % Change | -2.5% | -0.1% | -0.5% | -0.2% | -2.4% |
| Sac City- Established-Downtown/East Sac | Base | 19.9% | 9.0% | 15.6% | 3.4% | 2.8% |
| | % Change | -2.4% | 0.1% | -0.6% | -0.2% | -2.3% |
| Sac City- Established-South Sacramento | Base | 24.7% | 26.8% | 25.2% | 5.4% | 6.3% |
| | % Change | -1.8% | -0.1% | -0.5% | -0.2% | -2.1% |
| Sac County- Corridor- Florin Rd | Base | 28.4% | 41.8% | 24.0% | 5.3% | 6.1% |
| | % Change | -1.8% | -0.1% | -0.5% | -0.2% | -2.2% |
| Sac County- Corridor- Franklin Blvd 2 | Base | 31.6% | 46.1% | 27.1% | 6.3% | 7.7% |
| | % Change | -2.1% | 0.1% | -0.6% | -0.2% | -1.4% |
| Sac County- Corridor- Stockton Blvd 1 (14th Ave to Florin Rd) | Base | 28.7% | 49.9% | 25.6% | 6.2% | 7.6% |
| | % Change | -2.0% | 0.0% | -0.6% | -0.2% | -2.2% |
| Sac County- Corridor- Stockton Blvd 2 (Florin Rd to Mack Rd) | Base | 26.3% | 40.4% | 27.9% | 6.4% | 7.0% |
| | % Change | -1.9% | 0.1% | -0.5% | -0.2% | -1.3% |
| Sac County- Established-South Sacramento | Base | 25.7% | 32.2% | 25.2% | 5.4% | 6.4% |
| | % Change | -1.9% | 0.0% | -0.6% | -0.2% | -1.8% |

***Future Scenario Key*** | **Bold** Future scenario change > ± 5% | Future scenario % change (from 2012) in expected direction

[a] Percent change from base value

## *County Level*

Table 26 shows mean change in built environment inputs for the base versus future case at the Sacramento County level. Regional accessibility increased substantially in the future case (+36.5%). The retail/office FAR increased by about 18%, while commercial and residential access indices increased in the future case by about 14%. Overall walkability increased by +9.2% at the county level. Built environment inputs capturing transit, road network, and park conditions were unchanged between 2012 and 2036.

**Table 26. Base *versus* future change for built environments inputs (Sacramento County level)**

| Built environment inputs | | Base Case (2012) | Mean % difference in values between 2012 and 2036* |
|---|---|---|---|
| **Land Use** | Retail/office floor-to-area ratio | 0.11 | **18.2%** |
| | Net residential density | 5.2 | 6.6% |
| | Mixed land use index | 0.19 | **8.0%** |
| **Destination and Accessibility** | Distance to nearest education (truncated at 2000m) | 1078.9 | -3.8% |
| | Distance to nearest retail (truncated at 2000m) | 829.8 | **-8.0%** |
| | Dwelling unit accessibility | 240,181.2 | **29.1%** |
| | Employment accessibility | 231,602.2 | **46.3%** |
| | Residential access index | -1.5 | **13.5%** |
| | Commercial access index | -4.2 | **13.7%** |
| | Regional access index | -1.4 | **36.5%** |
| | Walkability index (standard) | -4.1 | **9.2%** |
| **Transit** | Count of transit stops/stations w/n 1km | 15.7 | 0% |
| | Distance to nearest transit (truncated at 2000m) | 1,201.9 | 0% |
| | Transit access index | -1.2 | 0% |
| | Any rail within 1km (0=no, 1=yes) | 6.6% | 0% |
| **Road** | Intersection density (intersections per square mile) | 57.0 | 0% |
| | Network connectivity index | -1.82 | 0% |
| | Major road exposure index | 1.6 | 0% |
| **Park** | Acreage of park w/n 1km buffer | 45.0 | 0% |
| | Distance to nearest park (truncated at 2000m) | 777.5 | 0% |
| | Park access index | -0.42 | -0.1% |

*Grid level % difference determined, formula = ((2036-2012)/2012). Unweighted mean of all grid % difference values in the county.

| ***Future Scenario Key*** | **Bold** | Future scenario change > ± 5% | | Future scenario % change (from 2012) in expected direction |
|---|---|---|---|---|

Table 27 and Table 28 shows mean physical activity and health outcomes at the Sacramento County level between the base and future case. Among adults, outcomes predicting the time spent walking and biking had the largest changes in the future case of +6.7% and +6.9% respectively. The senior age group also had positive change in time spent walking (+6.1%). The proportion of obese adults and seniors decreased by 1.8% and 1.7% respectively, while mean reduction in diabetes incidence was 1.7% for the adult age group and 0.9% for the senior age group.

Time spent walking also increased for the children (+5.9%) and teen (+3.8%) age groups in the future case. Likelihood of walking to school increased slightly for both age groups (+2.1% for children; +1.5% for teens). The percentage of children with body weights classified as obese dropped by an average of 2.9% in the future case; the teen cohort also had a reduction in obesity, although to a lesser extent than the child age group (-0.8%).

**Table 27. Sacramento County Level Mean Physical Activity and Health Outcomes –Adults and Seniors** *(Population-weighted mean for 42,000+ 150m grids)*

| Outcomes by age group | Base Case (2012) | % change between 2012 and 2036 |
|---|---|---|
| **Adults (18-65)** | | |
| CHTS Daily Per Capita Recreation PA (min/day) | 15.3 min | -0.2% |
| CHTS Daily Per Capita Walking (min/day) | 6.8 min | **6.7%** |
| CHTS Daily Per Capita Biking (min/day) | 1.1 min | **6.9%** |
| CHTS Daily Per Capita Auto (min/day) | 67.3 min | 0.2% |
| Obese Population (%) | 24.9% | -1.8% |
| Poor Health Population (%) | 18.2% | 0.0% |
| High Blood Pressure (%) | 23.3% | -0.6% |
| Heart Disease (%) | 5.0% | -0.2% |
| Diabetes - Type 2 (%) | 5.1% | -1.7% |
| **Seniors (+65 years)** | | |
| CHTS Daily Per Capita Recreation PA (min/day) | 13.8 min | 1.4% |
| CHTS Daily Per Capita Walking (min/day) | 4.5 min | **6.1%** |
| CHTS Daily Per Capita Auto (min/day) | 58.8 min | -0.3% |
| Obese Population (%) | 22.2% | -1.7% |
| Poor Health Population (%) | 19.4% | 0.9% |
| High Blood Pressure (%) | 57.6% | 0.1% |
| Heart Disease (%) | 18.5% | -1.0% |
| Diabetes - Type 2 (%) | 15.4% | -0.9% |
| Poor Health Population (%) | 4.3% | 0.1% |

***Future Scenario Key*** **Bold** Future scenario change > ± 5% | (shaded) Future scenario % change (from 2012) in expected direction

**Table 28. Sacramento County Level Mean Physical Activity and Health Outcomes – Teens and Children**
*(Population-weighted mean for 42,000+ 150m grids)*

| Outcomes by age group | Base Case (2012) | % change between 2012 and 2036 |
|---|---|---|
| **Children (< 12 years)** | | |
| CHTS Daily Per Capita Recreation PA (min/day) | 33.3 min | 0.1% |
| CHTS Daily Per Capita Walking (min/day) | 6.8 min | **5.9%** |
| CHTS Daily Per Capita Auto (min/day) | 47.4 min | 0.1% |
| Days with > 60 minutes of physical activity | 4.6 | -0.3% |
| Likelihood of walking to School (%) | 38.1% | 2.1% |
| BMI Percentile | 67.38 | -0.6% |
| Obese Population (%) | 30.9% | -2.9% |
| Poor Health Population (%) | 4.3% | 0.1% |
| **Teens (12-17 years)** | | |
| CHTS Daily Per Capita Recreation PA (min/day) | 31.8 min | -2.2% |
| CHTS Daily Per Capita Walking (min/day) | 8.9 min | 3.8% |
| CHTS Daily Per Capita Auto (min/day) | 47.1 min | -1.3% |
| Days with > 60 minutes of physical activity | 3.4 | -0.6% |
| Likelihood of walking to School (%) | 48.5% | 1.5% |
| BMI Percentile | 60.96 | 0.0% |
| Obese Population (%) | 15.8% | -0.8% |
| Poor Health Population (%) | 5.8% | 1.2% |

***Future Scenario Key*** **Bold** Future scenario change > ± 5% — Future scenario % change (from 2012) in expected direction

## Conclusions

A health impact assessment scenario planning methodology has been developed and successfully piloted in two regions of California showing considerable impacts of alternative approaches to making land use and transportation investment decisions. This methodology was made possible by spatially integrating the California Health Interview Survey and the California Household Travel Survey with a highly detailed parcel-level built environment database consistently developed across 5 major urban areas of California. This study represents an unprecedented level of access to, and leveraging of, existing data. The resulting five region methodology presents a population over 25,000,000 people and supported creation of age and income specific models and results.

Predictions made by the methodology in pilot testing were validated against external data sources, including at the county level using the Behavioral Risk Factor Surveillance System (BRFSS) and the Nationwide Household Travel Survey (NHTS). Based on the available CHTS and CHIS sample sizes, our county-level predictions are most equivalent to the accuracy we might expect from applying the models at the Census block group level, which range in size from 600-3,000 people.

Key built environment inputs found to have significant impacts on travel and health outcomes included:

**Table 29: Key Built Environment Inputs**

| | |
|---|---|
| | Retail/office floor-to-area ratio |
| | Net residential density |
| | Mixed land use index |
| **Destination and Accessibility** | Distance to nearest education (truncated at 2000m) |
| | Distance to nearest retail (truncated at 2000m) |
| | Dwelling units |
| | Employment |
| | Residential access |
| | Commercial access index |
| | Regional access index |
| | Walkability index (standard) |
| **Transit** | Count of transit stops/stations w/n 1km |
| | Distance to nearest transit (truncated at 2000m) |
| | Transit access index |
| | Rail within 1km (0=no, 1=yes) |
| **Roadways** | Intersection density (intersections per square mile) |
| | Network connectivity index |
| | Major road exposure index |
| **Parks** | Acreage of park within 1km buffer |
| | Distance to nearest park (truncated at 2000m) |
| | Park access index |

Key outcomes of interest included:

- **Physical Activity**
    - Variable categories included transportation walking, recreational walking, recreational moderate activity (excludes walking) and recreational vigorous activity
    - To address zero-inflated distributions, each category was divided into binary (yes or no activity) and two continuous components (minutes and metabolic equivalent).
- **Obesity**
    - Body mass index; with two categorical variables for overweight or obese, and obese, but not overweight
- **Health outcomes**
    - **High blood pressure** (if ever diagnosed by a doctor)
    - Presence of **heart disease** (if ever diagnosed by a doctor)
    - Type II **Diabetes** (if ever diagnosed by a doctor)
    - **Self-reported poor/fair health** (versus good/very good/excellent)

The specific health outcomes available for children and teens varied slightly:

- **Physical activity** was calculated as the number of days with at least 60 minutes of physical activity in the last week and any walking/biking to school during past week.
- **Obesity** measures are based upon BMI index percentiles.
- **Health outcomes** were limited to self-report poor/fair health.

Based on a 1 decile difference for each built environment variable for the CHIS and CHTS samples, the largest error between the mean sample observed outcome and mean base predicted outcome for CHIS models was 2.6% for adult diabetes, and in the majority of cases, the error was less than 1%.

Pilot application of the methodology was successful in both Sacramento (SACOG) and Orange County (SCAG) showing significant health benefits (with variation across age) of transit investment, increased mix of land uses, improved walkability, and access to parks.

## Next Steps

Educating local health, transportation, and planning departments based on the results of this project is an important next step in the evolution of health impact modeling in California. Publishing the results from the analysis in scientific journals is also a key objective of the study team, and applying the methodology in a range of other settings, including the current SCS process in Southern California, will be important to better understand how it operates in different demographic and study conditions. Evaluating how users can summarize and interpret the volumes of information the generated and how results are applied will also be important.

Additional research is required to incorporate the health-related fiscal impacts of alternative scenarios and some work is already underway on this critical topic. Decision makers need to understand how alternative approaches to land development and transportation investment impact financial bottom lines. Answering questions such as, "How much health care cost savings may result for different population subgroups as a result of different types of transit investment and improvements in walkability?" and "How much land value may increase based on where active transportation infrastructure is located?"

Research is also required to determine the relative health and cardiovascular impact from exposure to air pollution versus increases in physical activity found in more walkable neighborhoods. Further work is required to understand pedestrian safety impacts of changes to transportation infrastructure and land use changes that in turn generate walk trips. Objective data on physical activity is required to better understand how changes in built form impact actual activity levels and related health outcomes – noting that self-reported physical activity is often inaccurate.

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