UrbanFootprint

Technical Documentation
Model Version 1.0

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Contents

List of Figures

List of Tables

CHAPTER 1
Introduction

The UrbanFootprint model is a land use planning, modeling and data organization framework designed to facilitate more informed planning by practitioners, public agencies, and other stakeholders. Built on fully open-source software platforms and tools, UrbanFootprint requires no proprietary software of any kind. Its development is led by Calthorpe Associates, a planning and urban design firm headquartered in Berkeley, California.

UrbanFootprint comprises a suite of tools and analytical engines that decrease the time and resources required for land use scenario development, while significantly increasing the technical capacity of state, regional, and local users to analyze the fiscal, environmental, transportation, and public health impacts of plans and policies. Moreover, it provides a common data framework within which planning efforts at various scales can be integrated and synced.

The model currently includes analytical engines that produce results for the following metrics (with more to come as the model is advanced through deployment and research-based activities):

- Land consumption
- Vehicle miles traveled (VMT), travel mode, and fuel consumption
- Transportation greenhouse gas (GHG) and air pollutant emissions
- Building energy and water consumption, costs, and related GHG emissions
- Household costs for housing, transportation and utilities
- Public health impacts and costs (physical activity/weight-related, pollutant/respiratory-related, and pedestrian-safety)
- Local fiscal impacts (capital infrastructure and operations and maintenance costs, and tax/fee revenues)

UrbanFootprint Work Flow and Scenario Development Process

Scenario-based planning with UrbanFootprint involves four stages: data cleaning and organization, the translation of existing plans, scenario development, and scenario analysis. This document describes how UrbanFootprint works through each of these stages to arrive at clearly defined scenarios and results.

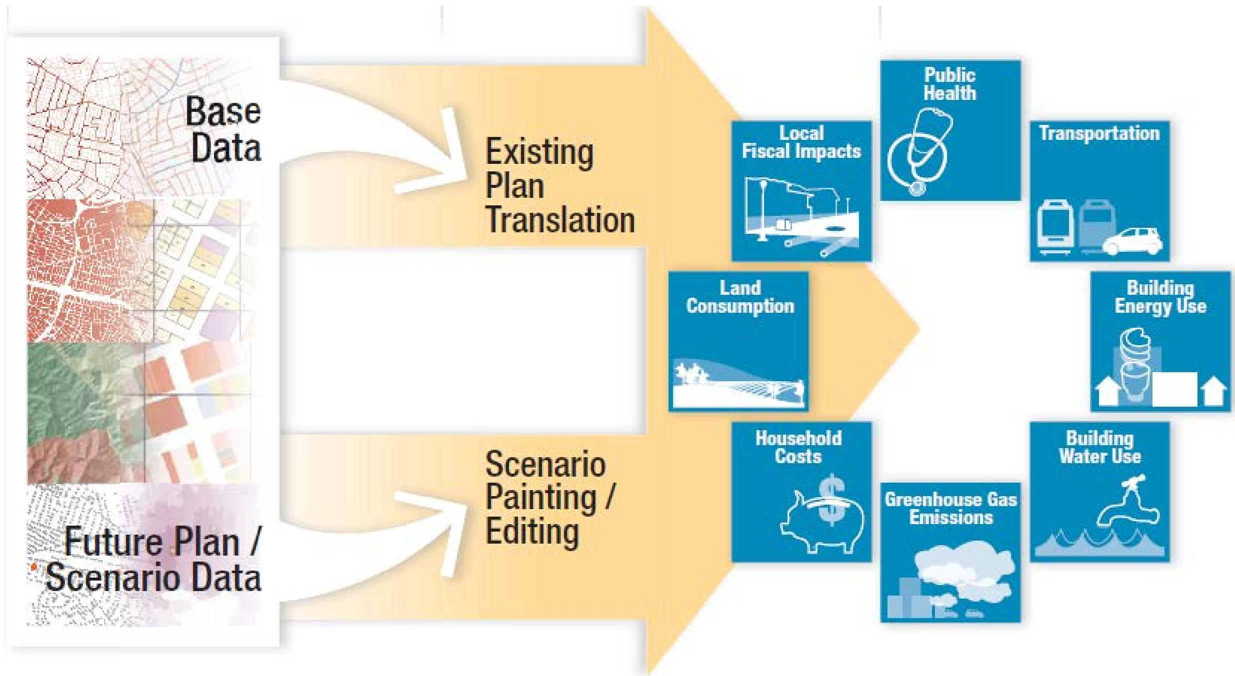

Figure 1-1: UrbanFootprint Work Flow Diagram

A note on geography: At version 1.0, UrbanFootprint uses a 150-meter polygrid as its native geographic resolution. In future versions (currently under development), however, it will be able to work at any level of geography, and more specifically tax lot parcels. This shift from normalized polygrids to cadastral geography is driven by the needs of regional governments to support local jurisdictions using the geographic resolution at which planning and development takes place. Throughout this document, references to the “grid” thus refer to functionality at version 1.0 of UrbanFootprint, which will soon transition to other levels of geography.

CHAPTER 2
Base Data Loading

UrbanFootprint scenarios are built upon a base-year grid that describes the existing environment. This highly detailed "canvas" of data constitutes a baseline assessment of land use, demographic characteristics, and other conditions, providing the context for scenario painting and the foundation for analysis by the various model engines. Base loading processes involve cleaning, compiling, and processing of geographic and tabular data from a wide variety of sources.

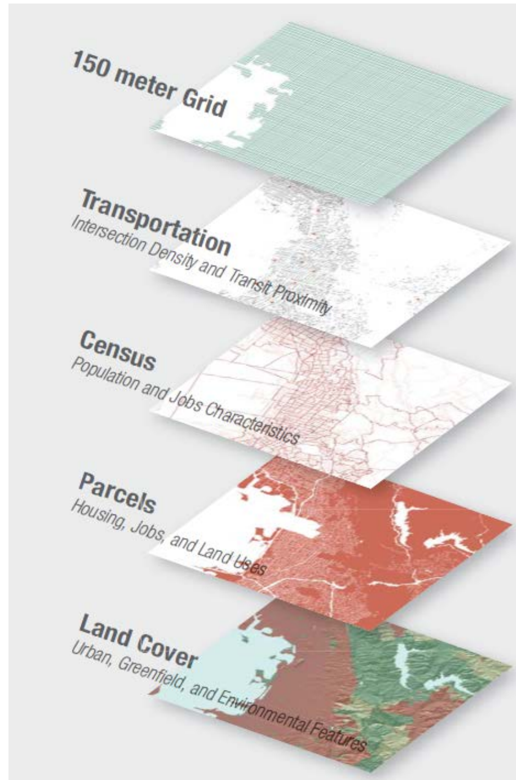

Figure 2-1: Base Data Loading Layers

UrbanFootprint's base year load seeks not just to compile data from different sources, but to process that data such that demographic attributes can be assigned to smaller levels of geography than that at which the primary data source is provided, and to parse data from different sources to inform analyses of base year conditions. For instance, census and other demographic data at the block, block group, tract, county, and region is assigned via rates to individual parcels and grid cells. Data concerning environmental features (water bodies) and protected lands (parks) is combined with remote-sensed data to produce an assessment of existing urbanized areas, existing constrained areas and areas available for future greenfield development.

UrbanFootprint uses a series of scripts to normalize data of varying type and scale from a wide range of sources and import them into the model analysis grid. The base loading process brings a range of data types together into the model's 5.5-acre (150 meter x 150 meter) grid. These include: land cover and environmental features; parcel-based data on housing, employment, and population; Census population, housing, and jobs characteristics; control total data from MPOs or other agencies, generally at the traffic analysis zone (TAZ) resolution; and roadway and transit data. These data types are described generally below first, and then detailed in the following subsections.

Land Cover and Environmental Features

UrbanFootprint classifies the landscape into three broad land type categories: urban, greenfield and constrained. Urban land includes lands that have already been developed. Constrained land includes water and lands legally or physically prevented from developing. Greenfield land includes all other non-urban potentially-developable areas. In California, the primary dataset used to classify land as either urban or greenfield is the California Farmland Mapping and Monitoring Program (FMMP) dataset. Constrained lands include protected areas defined by the California Protected Areas Database (CPAD) dataset, as well as water bodies as defined by a combination of: the California Spatial Information Library (CASIL) 'Polygon Hydrologic Features' dataset; the water features contained in the FMMP dataset; and the Tele-Atlas North America (TANA) 'U.S. and Canada Water Polygons' dataset.

Parcel Data

Assessor's tax parcel data (cadastral data) is the finest geographical resolution to which data is assigned in the base data loading process. Existing land use attributes are "crosswalked" into UrbanFootprint's building types framework, which is then used as the basis for allocating dwelling units and employees to each parcel (based on a feedback loop involving control totals at the Traffic Analysis Zone [TAZ] or another, higher, level of geography), as well as assessing lot coverage for the purposes of energy use, water consumption, and other analyses.

Census and Related Data

UrbanFootprint generates raw counts of population, dwelling units, jobs, and other demographic variables at the parcel and grid level using a rate file generated from US Census data. This rate file is generated using a combination of: Census Summary File 1 (SF1: blocks, from the short form); Summary File 3 (SF3: block groups, from the long form); Census Transportation Planning Package (CTPP2: block groups); Longitudinal Employer-Household Dynamics (LEHD: blocks); American Community Survey (ACS) and other data products, which in the State of California include job estimates and counts from the California Employment Development Department (EDD) and population counts and estimates from the California Department Of Finance (DOF).

Transportation Features

Every grid cell is assigned a distance to the nearest passenger rail or other fixed-guideway (light rail or bus rapid transit) transit stop. This information is used by several of UrbanFootprint's engines, including travel and public health. A dataset of walkable street intersections, which is critical for Place Type translation, travel, public health, and other UrbanFootprint functions, was produced using street centerline data from Census Topologically Integrated Geographic Encoding and Referencing (TIGER) data.

Topological Cleaning and Formatting of Geometries

Base year input data comes from a wide range of sources in a variety of formats, and can often be of varied quality in regards to topological errors and intended geometric relationships. UrbanFootprint requires that each input geometry be topologically flat and contain a unique ID for each feature. This means that a file is free of topological errors as well as stacked and overlapping geometries. In addition to this, for parcel files, stacked parcel geometries often reflect the number of condo units in a parcel. These cases require additional processing, not only to make them a single geometry, but also to count the number of geometries in order to provide dwelling unit counts for use later in the model. Parcel files in UrbanFootprint also require that all road geometries be removed. Road geometries are removed because they are not candidates for demographic parcel modeling and create issues for calculating specific fields in UrbanFootprint.

At UrbanFootprint version 1.0, the topological cleaning of any input geometry as well as the further processing of parcel files is carried out using ArcInfo software prior to the data being loaded into the UrbanFootprint environment.[1]

General Topological Process

Using ArcInfo's Topology toolset, new datasets are cleaned and flattened with resulting files containing unique IDs and free of overlapping polygons. The general process for any geometry followed the following steps:

Step 1: Remove duplicate records and format unique ID. The native ID field is checked for duplicates and null values. If a duplicate is found, an action taken, i.e. duplicates are merged. If too many duplicates are found with no clear path for correction, a new field is created containing a unique serial ID in addition to the native ID field.

Step 2: Run topology and clean overlapping polygons. The file is then checked for overlapping geometries. First the file is topologically analyzed and the number of overlaps is counted. Features are then created for each overlap and then merged using the Eliminate tool to the neighboring polygon with the longest shared border.

Step 3: Simplify geometry. Simplify is then run on the result to reduce the number of vertices for each feature.

Step 4: Repair geometry. Repair geometry is run to fix any outstanding geometry issues.

Parcel File Formatting

In addition to the above cleaning process, parcel files require processing of stacked geometries and the removal of roads. The process for this follows these steps:

Step 1: Formatting Stacked Polygons. To check for and resolve stacked (completely overlapping) polygons that represent condo parcels, all records are dissolved on their spatial attributes (Shape_Area, Shape_Length, and the X and Y coordinates of the parcel centroid). A visual inspection of an aerial photo is then done to confirm that polygon counts corresponded to the number of condo units in a sample of parcel locations. A dwelling unit count field is added to the file to record how many polygons were dissolved into each resulting record.

Step 2: Removing road polygons. Polygons representing roads are deleted from the file. Three criteria are used to find these records. A thinness index is calculated (4*3.14* [Shape_Area])/([Shape_Length]* [Shape_Length]). A road-buffer area ratio is also calculated using 2010 Census roads data with a 1-meter buffer to determine the proportion of a feature that is covered by a road. Low thinness values and a

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[1] Future versions of UrbanFootprint will likely leverage the topology advancements made by PostGIS 2.0 to "internalize" the processing of topology (including topological cleaning) into UrbanFootprint's integrated modeling framework.

high road-buffer area ratio suggest a greater likelihood that the polygon represents a road. Finally, donut features are identified to eliminate them from the road selection since many apartment complex parking lots have low thinness values and high road-buffer area ratios, but have areas that are also donut polygons. The following selection criteria – which was visually tested for accuracy – was used to identify roads for deletion:

First Pass:

```
("Thinness" < 0.17 AND "ROAD_RATIO" > 0.09 AND "donut" = 0) OR
("Thinness" < 0.16 AND "ROAD_RATIO" > 0.085 AND "donut" = 0) OR
("Thinness" < 0.14 AND "ROAD_RATIO" > 0.08 AND "donut" = 0) OR
("Thinness" < 0.14 AND "ROAD_RATIO" > 0.075 AND "donut" = 0) OR
("Thinness" < 0.13 AND "ROAD_RATIO" > 0.071 AND "donut" = 0) OR
("Thinness" < 0.12 AND "ROAD_RATIO" > 0.055 AND "donut" = 0) OR
("Thinness" < 0.095 AND "ROAD_RATIO" > 0.04 AND "donut" = 0) OR
("Thinness" < 0.075 AND "ROAD_RATIO" > 0.03 AND "donut" = 0) OR
("Thinness" < 0.06 AND "ROAD_RATIO" > 0.025 AND "donut" = 0) OR
("Thinness" < 0.04 AND "ROAD_RATIO" > 0.09) OR
("Thinness" < 0.15 AND "ROAD_RATIO" > 0.16) OR
("Thinness" < 0.3 AND "ROAD_RATIO" > 0.20)
```

Second Pass:

```
(("Thinness" < 0.40 AND "ROAD_RATIO" > 0.125 AND "donut" = 0 AND "Acres" > 0.26)
OR
("Thinness" < 0.30 AND "ROAD_RATIO" > 0.115 AND "donut" = 0 AND "Acres" > 0.36) OR
("Thinness" < 0.26 AND "ROAD_RATIO" > 0.105 AND "donut" = 0 AND "Acres" > 0.41) OR
("Thinness" < 0.24 AND "ROAD_RATIO" > 0.1 AND "donut" = 0 AND "Acres" > 0.47) OR
("Thinness" < 0.19 AND "ROAD_RATIO" > 0.08 AND "donut" = 0 AND "Acres" > 0.53))
AND "DU" IS NULL
```

Once a geography file has been topologically cleaned and formatted, it is ready to be loaded into the UrbanFootprint PostgreSQL database.

Reference Dataset Creation

As part of a detailed modeling of the base environment, UrbanFootprint requires the synthesis of a wide range of datasets at different geographies and formats. To provide order to this process, a number of California-wide reference datasets were created from which data could be merged and stored. The primary reference datasets include a land type file containing broad land use categories, a walkable intersections file used to assess walkability and urban form, a transit proximity file for use in modeling transit relationships and a census rates file used to produce sub-block scale demographic variables. The methodology used in the creation of each of these reference datasets is detailed in the following section.

Land Type Data

The primary data product produced by UrbanFootprint's land type process is a seamless dataset showing where urban, greenfield and constrained areas exist in California. Urban areas can be considered those that are built up and dominated by hardscape features and buildings. Areas classified as greenfield consist of unprotected farmland, open space and all non-urban, non-conservation lands. Greenfield areas also define how new land consumption is accounted for in UrbanFootprint. Constrained areas are protected conservation lands, water bodies, parks and other use types which would not allow new urban growth in the future. The dataset was created using of a number of publically available GIS layers.

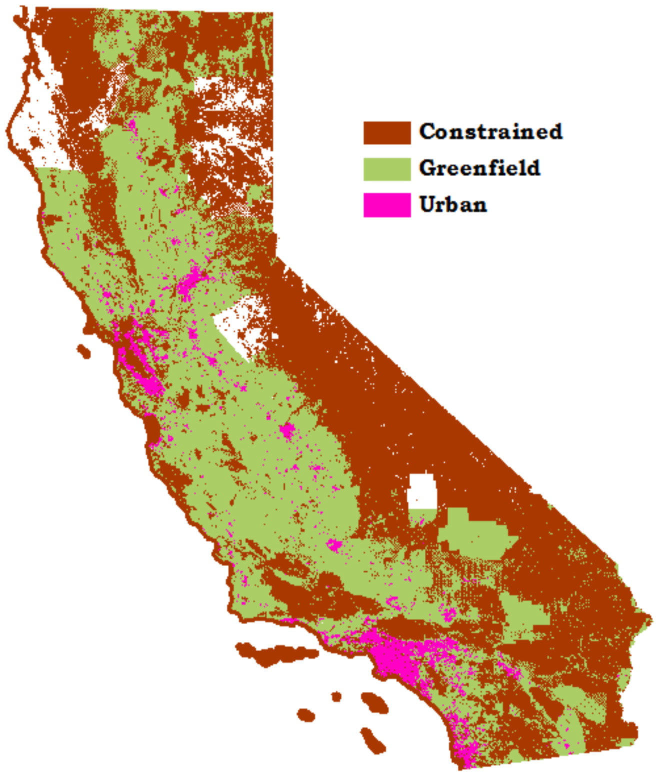


Figure 2-2: Land Type Map

Land Type Data Sources

The primary land cover classifications in the land type data set are urban, greenfield and constrained. Greenfield and urban land categories were defined using California's Farmland Mapping and Monitoring Program's (FMMP) dataset. Constrained lands included protected areas defined by the CPAD (California Protected Areas Database) dataset as well as water bodies as defined by the following datasets:

- The California Spatial Information Library (CASIL) 'Polygon Hydrologic Features' dataset, December 2003
- The water features contained in the Farmland Mapping & Monitoring Program (FMMP) data set, 2006
- The Tele-Atlas North America (TANA) 'U.S. and Canada Water Polygons' dataset, February 2007
- USGS Water features

Seamless Land Type Methodology

The process for creating the seamless land type data for California consists of a series of erase and merge operations after which attributes from the various datasets are reclassified into the land type categories of urban, greenfield and constrained. The general process is outlined in Figure 2-3**.**

For more specifics of the methodology, the process followed these steps:

Step 1: Cleaning input geometries. Each input file is topologically cleaned following the methodology previously described in the Topology cleaning and Formatting of Geometries section.

Step 2: Merging and formatting the constraints layers. The input datasets that included constraints data were spatially merged. These geometries included the CASIL, FMMP, TANA and USGS datasets. To merging the geometries, each was sequentially erased one from another and then merged with the final constraints layer. The result of this process was that all constraint features from each dataset were represented in the final Constraints classification.

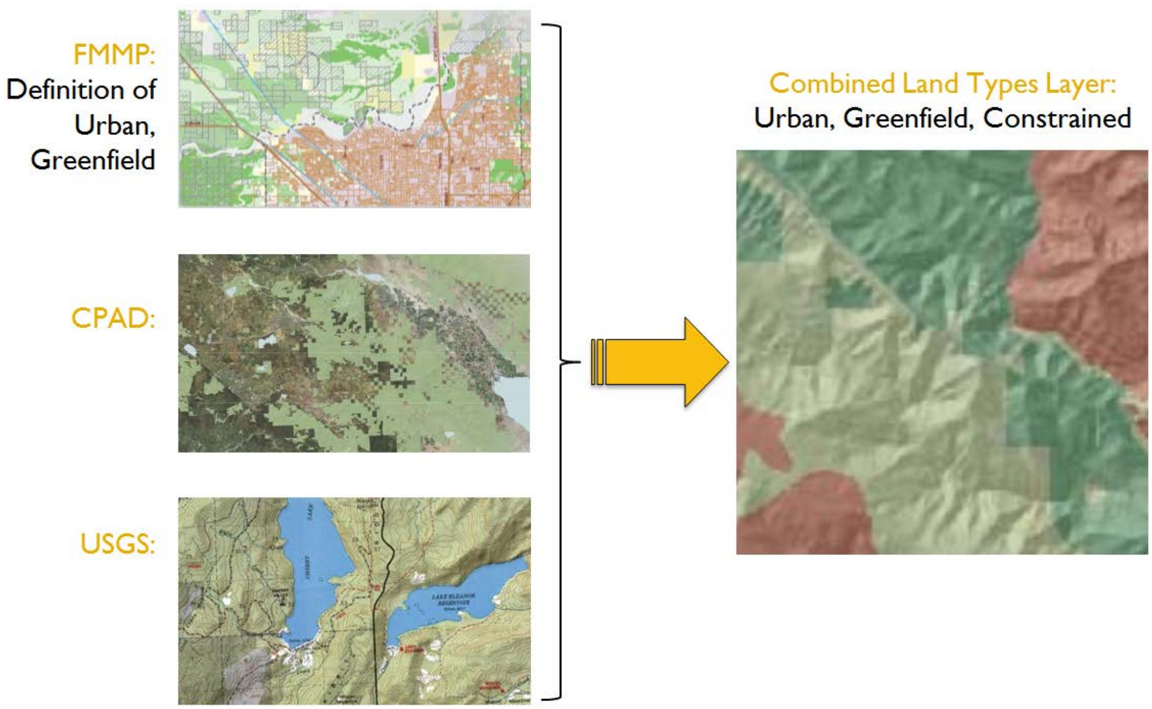


Figure 2-3: Input Data to the Land Typing Process

Step 3: Merging the constraints layer with the FMMP dataset. The aggregated constraints layer produced in the previous step was erased from and then merged to the FMMP dataset. This produced a temporary file with all the unclassified data and the associated geographies of the land type geometries.

Step 4: Reclassification of FMMP categories to urban and greenfield land type categories. The FMMP categories that represented urban and greenfield land types were reclassified into the corresponding urban and greenfield categories.

Step 5: Constraints fields were formatted to the land type schema. The fields and geometries created in the production of the constraints layer were reclassified to the standard constraints schema of the land type reference dataset.

Step 6: Topologically cleaning and repairing geometry on final land type file. The dataset was again topologically cleaned and repair geometry was run on the result. This last step finalized the process for producing the statewide land type data set and it was fully prepped for moving into the UrbanFootprint PostgreSQL database environment.

Transit Proximity Data

The transit proximity dataset is a full coverage statewide layer at the 150 meter grid cell scale with fields that include a number of proximity measures to a wide range of transit types. Proximity measures represent the buffered Euclidean distance of each grid cell to transit locations. There are a total of seven layers created for the transit proximity dataset, each relating to a time horizon and policy setting. The data is an aggregation of a wide range of publicly available datasets of existing and potential future transit locations and types. The years of 2005, 2035 and 2050 are represented in the layers, with the horizon years of 2035 and 2050 being split into three policy layers, trend, smart and ultra. The policy layers correspond to the following descriptions:

Trend: The trend policy layer represents the most likely near-term future transit locations given the committed project lists of currently-adopted Regional Transportation Plans (RTPs).

Smart: The Smart policy layer reflects future transit locations given expanded funding of transit infrastructure as compared to the base year.

Ultra: The Ultra policy layer reflects all planned or proposed transit locations to be built in a given horizon year without considering funding allocations. This would reflect the most progressive policy scenario for transit locations.

Transit Data Sources

The data sources used in the creation of the Transit Proximity layer include statewide and Regional Transportation Plan (RTP) datasets to model both the existing and future transit infrastructure locations. To produce the transit proximity grid, the model requires a point file representing transit location by type corresponding to the year and transit scenario. For each year and policy combination, a transit point file was created by aggregating state and regional transit datasets. The statewide datasets include publically available transit point data for existing infrastructure, while regional RTPs and other transportation planning documents[2] informed the location and type of future transit infrastructure locations. RTP data was classified into the different policy layers based on which funding category each transit location fit into.

[2] Such as the Regional Rail Plan in the San Francisco Bay Area: http://www.mtc.ca.gov/planning/rail/

Transit Fields

Using a point file representing transit stops from either a base year or a horizon year policy transit dataset, the distance variables listed in Table 2-1 are calculated for each grid cell.

Table 2-1: Transit Database Fields

Field Name	***Field Definition***
Tr_All_Grid	Boolean flag if transit stops of all types in the grid cell
Tr_All_QrtMi	Boolean flag if transit stops of all types within a 1/4 mile search radius
Tr_All_HalfMi	Boolean flag if transit stops of all types within a 1/2 mile search radius
Tr_All_ThreeQrtMi	Boolean flag if transit stops of all types within a 3/4 mile search radius
Tr_All_OneMi	Boolean flag if transit stops of all types within a one mile search radius
Tr_All_OneKm	Boolean flag if transit stops of all types within a one km search radius
Tr_HSR_Grid	Boolean flag if high speed rail stops in the grid cell
Tr_HSR_QrtMi	Boolean flag if high speed rail stops within a 1/4 mile search radius
Tr_HSR_HalfMi	Boolean flag if high speed rail stops within a 1/2 mile search radius
Tr_HSR_ThreeQrtMi	Boolean flag if high speed rail stops within a 3/4 mile *search* radius
Tr_HSR_OneMi	Boolean flag if high speed rail stops within a one mile search radius
Tr_HSR_OneKm	Boolean flag if high speed rail stops within a one km search radius
Tr_Ferry_Grid	Boolean flag if ferry stops in the grid cell
Tr_Ferry_QrtMi	Boolean flag if ferry stops within a 1/4 mile search radius
Tr_Ferry_HalfMi	Boolean flag if ferry stops within a 1/2 mile search radius
Tr_Ferry_ThreeQrtMi	Boolean flag if ferry stops within a 3/4 mile search radius
Tr_Ferry_OneMi	Boolean flag if ferry stops within a one mile search radius
Tr_Ferry_OneKm	Boolean flag if ferry stops within a one km search radius
Tr_Intercity_Grid	Boolean flag if intercity rail stops in the grid cell
Tr_Intercity_QrtMi	Boolean flag if intercity rail stops within a 1/4 mile search radius
Tr_Intercity_HalfMi	Boolean flag if intercity rail stops within a 1/2 mile search radius
Tr_Intercity_ThreeQrtMi	Boolean flag if intercity rail stops within a 3/4 mile search radius
Tr_Intercity_OneMi	Boolean flag if intercity rail stops within a one mile search radius
Tr_Intercity_OneKm	Boolean flag if intercity rail stops within a one km search radius
Tr_Commuter_Grid	Boolean flag if commuter rail stops in the grid cell
Tr_Commuter_QrtMi	Boolean flag if commuter rail stops within a 1/4 mile search radius
Tr_Commuter_HalfMi	Boolean flag if commuter rail stops within a 1/2 mile search radius
Tr_Commuter_ThreeQrtMi	Boolean flag if commuter rail stops within a 3/4 mile search radius
Tr_Commuter_OneMi	Boolean flag if commuter rail stops within a one mile search radius
Tr_Commuter_OneKm	Boolean flag if commuter rail stops within a one km search radius
Tr_Heavy_Grid	Boolean flag if heavy rail stops in the grid cell
Tr_Heavy_QrtMi	Boolean flag if heavy rail stops within a 1/4 mile search radius
Tr_Heavy_HalfMi	Boolean flag if heavy rail stops within a 1/2 mile search radius
Tr_Heavy_ThreeQrtMi	Boolean flag if heavy rail stops within a 3/4 mile search radius
Tr_Heavy_OneMi	Boolean flag if heavy rail stops within a one mile search radius
Tr_Heavy_OneKm	Boolean flag if heavy rail stops within a one km search radius

Field Name	Field Definition
Tr_All_Grid	Boolean flag if transit stops of all types in the grid cell
Tr_LRT_Grid	Boolean flag if light rail stops in the grid cell
Tr_LRT_QrtMi	Boolean flag if light rail stops within a 1/4 mile search radius
Tr_LRT_HalfMi	Boolean flag if light rail stops within a 1/2 mile search radius
Tr_LRT_ThreeQrtMi	Boolean flag if light rail stops within a 3/4 mile search radius
Tr_LRT_OneMi	Boolean flag if light rail stops within a one mile search radius
Tr_LRT_OneKm	Boolean flag if light rail stops within a one km search radius
Tr_BRT_Grid	Boolean flag if bus rapid transit stops in the grid cell
Tr_BRT_QrtMi	Boolean flag if bus rapid transit stops within a 1/4 mile search radius
Tr_BRT_HalfMi	Boolean flag if bus rapid transit stops within a 1/2 mile search radius
Tr_BRT_ThreeQrtMi	Boolean flag if bus rapid transit stops within a 3/4 mile search radius
Tr_BRT_OneMi	Boolean flag if bus rapid transit stops within a one mile search radius
Tr_BRT_OneKm	Boolean flag if bus rapid transit stops within a one km search radius
Tr_Streetcar_Grid	Boolean flag if streetcar stops in the grid cell
Tr_Streetcar_QrtMi	Boolean flag if streetcar stops within a 1/4 mile search radius
Tr_Streetcar_HalfMi	Boolean flag if streetcar stops within a 1/2 mile search radius
Tr_Streetcar_ThreeQrtMi	Boolean flag if streetcar stops within a 3/4 mile search radius
Tr_Streetcar_OneMi	Boolean flag if streetcar stops within a one mile search radius
Tr_Streetcar_OneKm	Boolean flag if streetcar stops within a one km search radius
Tr_Monorail_Grid	Boolean flag if monorail stops in the grid cell
Tr_Monorail_QrtMi	Boolean flag if monorail stops within a 1/4 mile search radius
Tr_Monorail_HalfMi	Boolean flag if monorail stops within a 1/2 mile search radius
Tr_Monorail_ThreeQrtMi	Boolean flag if monorail stops within a 3/4 mile search radius
Tr_Monorail_OneMi	Boolean flag if monorail stops within a one mile search radius
Tr_Monorail_OneKm	Boolean flag if monorail stops within a one km search radius
Tr_DMU_Grid	Boolean flag if DMU stops in the grid cell
Tr_DMU_QrtMi	Boolean flag if DMU stops within a 1/4 mile search radius
Tr_DMU_HalfMi	Boolean flag if DMU stops within a 1/2 mile search radius
Tr_DMU_ThreeQrtMi	Boolean flag if DMU stops within a 3/4 mile search radius
Tr_DMU_OneMi	Boolean flag if DMU stops within a one mile search radius
Tr_DMU_OneKm	Boolean flag if DMU stops within a one km search radius
Tr_BRT_lite_Grid	Boolean flag if BRT-lite stops in the grid cell
Tr_BRT_lite _QrtMi	Boolean flag if BRT-lite stops within a 1/4 mile search radius
Tr_BRT_lite _HalfMi	Boolean flag if BRT-lite stops within a 1/2 mile search radius
Tr_BRT_lite _ThreeQrtMi	Boolean flag if BRT-lite stops within a 3/4 mile search radius
Tr_BRT_lite _OneMi	Boolean flag if BRT-lite stops within a one mile search radius
Tr_BRT_lite _OneKm	Boolean flag if BRT-lite stops within a one km search radius
Tr_Cablecar_Grid	Boolean flag if cable car stops in the grid cell
Tr_Cablecar_QrtMi	Boolean flag if cable car stops within a 1/4 mile search radius
Tr_Cablecar_HalfMi	Boolean flag if cable car stops within a 1/2 mile search radius
Tr_Cablecar_ThreeQrtMi	Boolean flag if cable car stops within a 3/4 mile search radius
Tr_Cablecar_OneMi	Boolean flag if cable car stops within a one mile search radius

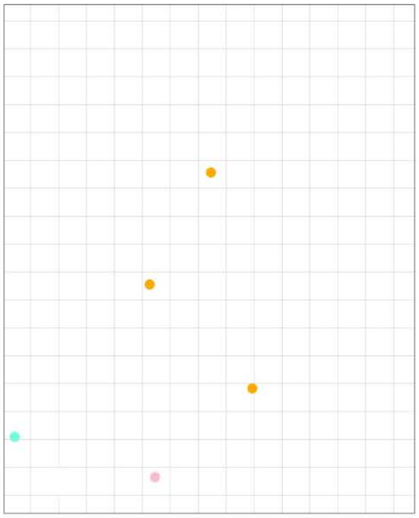
Field Name	Field Definition
Tr_All_Grid	Boolean flag if transit stops of all types in the grid cell
Tr_Cablecar_OneKm	Boolean flag if cable car stops within a one km search radius
Tr_Maglev_Grid	Boolean flag if maglev stops in the grid cell
Tr_Maglev_QrtMi	Boolean flag if maglev stops within a 1/4 mile search radius
Tr_Maglev_HalfMi	Boolean flag if maglev stops within a 1/2 mile search radius
Tr_Maglev_ThreeQrtMi	Boolean flag if maglev stops within a 3/4 mile search radius
Tr_Maglev_OneMi	Boolean flag if maglev stops within a one mile search radius
Tr_Maglev_OneKm	Boolean flag if maglev stops within a one km search radius
Tr_PeopleMover_Grid	Boolean flag if people mover stops in the grid cell
Tr_PeopleMover_QrtMi	Boolean flag if people mover stops within a 1/4 mile search radius
Tr_PeopleMover_HalfMi	Boolean flag if people mover stops within a 1/2 mile search radius
Tr_PeopleMover_ThreeQrtMi	Boolean flag if people mover stops within a 3/4 mile search radius
Tr_PeopleMover_OneMi	Boolean flag if people mover stops within a one mile search radius
Tr_PeopleMover_OneKm	Boolean flag if people mover stops within a one km search radius

Euclidean Distance Transit Proximity Methodology

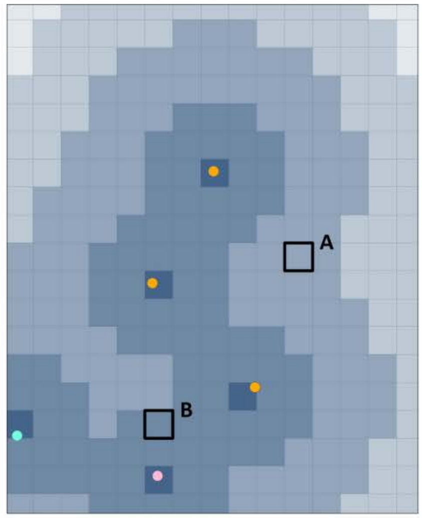
To create the transit proximity datasets, the model combines the 150 meter grid and the transit point's layer for a given year and policy scenario. In the first step, model runs a selection of surrounding grid cells within a given radius. For each of those grid cells, the model populates the variables listed in the table above with a Boolean '1' (yes) or '0' (no) value if transit locations intersect with the selection criteria. Field values are calculated for the following five mutually exclusive grid cell selections:

DIAGRAM A.

Data Inputs
Transit Points and Grid



Loaded Grid
Transit Proximity Variables



Sample Grid Variables
Transit Proximity (1 = yes)

Grid Sample A

Tr_Commuter_onemile	1
Tr_Heavy_halfmile	1 *
Tr_Heavy_3quartmile	1

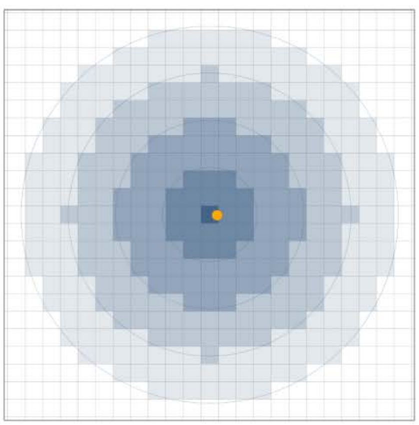
Grid Sample B

Tr_Ferry_halfmile	1
Tr_Commuter_quartmile	1
Tr_Heavy_halfmile	1 *
Tr_Heavy_onemile	1

All other variables = 0 (no).

* These proximities apply to more than one transit stop. The model, however, will not indicate the number of stops within a given distance, but simply the presence

DIAGRAM B. Grid Loading Cell Selection Method
Cell proximity is determined according to the location of cell centroid relative to a buffer. The pattern of cell selection, and number of cells selected, is identical for all transit points.



- Commuter rail stop
- Ferry stop
- Heavy rail stop
- 'Crow Flies' buffers (¼, ½, ¾, and one mile)
- Cell that contains transit stop (1 cell)
- Cells with centroids within ¼ mile of, but not containing, stop (20 cells)
- Cells with centroids between ¼ and ½ mile of stop (68 cells)
- Cells with centroids between ½ and ¾ mile of stop (108 cells)
- Cells with centroids between ¾ and one mile of stop (160 cells)

Figure 2-4: Transit Proximity Methodology

1. The cell containing the transit stop *(1 grid cell)*
2. The cells with their centroids within ¼ mile of, but not containing, the centroid of the cell containing the transit stop *(20 grid cells)*
3. The cells with their centroids within ¼ and ½ mile of the centroid of the cell containing the transit stop *(68 grid cells)*
4. The cells with their centroids within ½ and ¾ mile of the centroid of the cell containing the transit stop *(108 grid cells)*
5. The cells with their centroids within ¾ and one mile of the centroid of the cell containing the transit stop *(160 grid cells)*

Since all selections are determined based on a distance from the centroid of the central grid cell containing the transit stop, the grid cell selection pattern will be identical for each transit stop. Each transit stop will, therefore, produce transit proximity variable calculations for 357 grid cells: 1 center cell, 20 quarter mile buffer cells, 68 half mile buffer cells, 108 three-quarter mile cells, and 160 one mile buffer cells. This pattern is further illustrated in Figure 2-4.

Walkable Street Intersection Data

The street intersections dataset provides statewide coverage of intersection counts as well as buffered counts and densities of intersections at the 150-meter grid scale. The street intersection density fields created in this process are one of the primary variables in quantifying the qualitative nature of urban form and are key variables used walkability analysis. As a result, the walkable intersection dataset is widely used as an input variable in UrbanFootprint. Areas with greater than 150 intersections per square mile are generally considered walkable: small blocks mean shorter distances between intersections; and a greater number of intersections usually means a greater number of routes for the pedestrian to choose among. Areas with fewer than 150 intersections per square mile tend to be automobile-oriented and less pedestrian-friendly: large blocks with fewer intersections mean fewer route choices for the pedestrian; areas designed with large blocks tend to be automobile-oriented with large, fast roads; and areas with low levels of intersection density also tend to lack pedestrian amenities such as sidewalks.

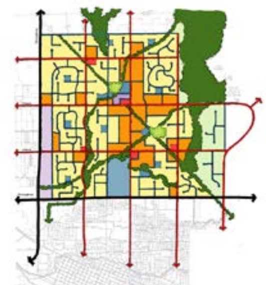


Figure 2-5: Diagram of a street network with fewer than 150 intersections per square mile.

Figure 2-6: Diagram of a street network with greater than 150 intersections per square mile.

The following section details the inputs and methodology for creating this statewide dataset.

Intersection Input Data

The datasets used to create the UrbanFootprint intersections layer were the Census Tiger Streets feature dataset and the statewide 150-meter grid. The Census Tiger Streets dataset was processed to convert street intersection nodes to point features and to remove 'non-walkable' intersections. 'Non-walkable' intersections relate to highway on and off ramps, cul-de-sacs, and duplicate intersection points, which do not correspond with walkability and urban form. The intersections were then loaded into the grid, from which proximity and density fields are calculated to produce the final dataset.

Walkable Street Intersection Fields

The fields created in the full coverage walkable intersection dataset include counts and density fields for a number of Euclidean distance buffers from each grid cell. The full list of fields is found in Table 2-2.

Table 2-2: Walkable Intersection Fields

Field Name	Field Definition
intersection count	Number of intersections within a grid cell
intersection_density_sqmi	number of intersections within a square mile (adjusted for edge effects)
intersection_density_sqkm	number of intersections within a square kilometer (adjusted for edge effects)
intersection_count_onekm	number of intersections within one kilometer
intersection_count_qtrmi	number of intersections within a quarter mile

Walkable Intersection Processing Methodology

Step 1: Removing freeways. The first pass through the dataset removes streets coded as freeways, highways, and their associated on- and off-ramps. A second pass manually identifies the centerlines that have not received the proper code, but fall into the above categories.

Step 2: Collapsing Boulevards. A typical representation of a boulevard in TIGER data will have two centerlines, one for each direction of traffic. These are collapsed into a single line by searching for parallel segments within a certain radius.

Step 3: Merge/Explode. The remaining geometries are 'cleaned' by joining all the lines into a multi-line, and then splitting them back out into separate pieces wherever there is a branching point. This step eliminates nodes between segments that do not represent street intersections.

Step 4: Remove Cul-de-sacs. A final line-processing step is to identify and remove roads that only connect to the street network at a single point, and which have a length of less than 300 meters. This covers streets that could be considered cul-de-sacs and which do not contribute to the walkability of the network.

Step 5: Generate Intersection Points. The resulting set of streets is used to generate points at the intersection of any two lines. These points are the output: walkable intersection points.

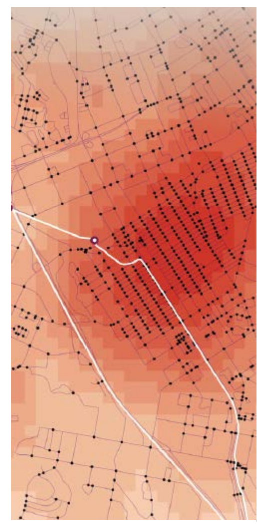


Figure 2-7: Walkable intersections and intersection density

Intersection Counts and Density Methodology

The primary inputs to this process are the processed walkable intersection point dataset and the 150-meter grid. These layers are combined using spatial operations after which a combination of attribute and spatial calculations are used to produce the final walkable intersection table at the 150-meter grid scale. The process for creating the necessary fields follows these general steps:

Step 1: Intersecting grid and walkable intersection points. The first step in the process is to produce intersection counts at the grid scale. These are produced by intersecting the walkable intersection point dataset with the 150-meter grid and counting all points that intersect each grid cell.

Step 2: Calculating buffered walkable intersection counts. Buffered intersection count fields are produced for two buffer distances: a quarter mile, and one kilometer. Neighboring grid cells within each buffer distance were selected, and the intersection counts from those cells tallied, along with how many grid cells were found within the buffer distance. Buffers were generated using the Euclidean distance from the centroid of each grid cell.

Step 3: Calculating buffered intersection densities. Intersection density was calculated to adjust for edge effects in the buffered intersection count process and to provide a more robust portrayal of the walkability of a given environment. The model produces two intersection density fields, intersection density per square mile and intersection density per square kilometer.

Simple division of the buffered intersections count by an area of the buffer would have the effect of lowering the intersection density for grid cells located at the edge of the grid, where there was no opportunity to find intersections. To avoid this edge effect, the buffered intersection count was divided by the total area of the grid cells that were found within the buffer to achieve the Buffered Intersection Density per acre. This figure was multiplied by the appropriate factor to get densities in the output measures of km^2 and mi^2 (see Equation 2-1).

Equation 2-1: Intersection Density within any buffer distance

$$I_d = \left(\frac{I_c}{A}\right) * C_f$$

Where:
I_d = Buffered intersection density
Ic = Count of intersections within buffered distance
A = Area of grid cells with the buffer
Cf = Conversion factor for acres to square miles or square kilometers

Census Rate Dataset

The UrbanFootprint Census Rate File created for the Vision California project is a statewide dataset from the Year 2010 Census SF1 (block), the 2010 SF3 (block group), the 2000 CTPP (block group), and 2010 Longitudinal Employer-Household Dynamics (block) data sets. The file is organized at the Census block scale and includes rates of various demographic, housing, and jobs characteristics relative to total population, dwelling units, households, and jobs.

Whereas the original data sources provide raw counts of population, dwelling units, households, and jobs across various subclasses, the UrbanFootprint Census Rate File contains a series of percentage variables describing the proportion of people, dwelling units, households, and jobs that fall into these subclasses.

Examples of the types of variables included in the Census Rate File include: the percent of households that fall into different income ranges; the percent of residences that are multifamily 2 to 4 or multifamily 5 plus; the percent of jobs that are NAICs subcategories of retail services, office services, public administration, manufacturing, etc.; and so on.

Census Data Sources

The goal of this process was to produce a file incorporating Census and LEHD data at the block scale that describes the rates of various demographic, housing, and jobs characteristics relative to the number of households, population, employees etc. Rate fields represent the ratio between a universe of data and its subsets, such as the ratio of single-family dwelling units to all dwelling units or the ratio of households with one car to all households.

The following data were used to create the Census Rate File:

Block geography

SF1 (short form) 2010 – including overview population and housing data related to gender, race, housing occupancy and ownership rates, and broad age categories for every *block* in the state

Longitudinal Employer-Household Dynamics (LEHD) 2010 – including jobs sector data for about *1/3rd of the blocks* in the state

Block Group geography

SF3 (long form) 2010 – including extensive population and housing data related to housing types and years built, detailed age distribution, household incomes, household vehicle ownership, householder tenure, school enrollment, educational attainment, labor force participation by sector, and employed resident commute modes and times for every *block group* in the state

Census Transportation Planning Package (CTPP) 2000 – including jobs by sector, worker commute modes and times, worker vehicle ownership, and vehicles parked at the workplace for every block group in the state

Census Rate Fields

The variables that follow were each calculated as a percentage of the universe of dwelling units, households, population, or jobs, respectively.

Dwelling units:

- Occupancy rate
- Percent detached single family, attached single family, 2-4 unit multifamily, 5-plus unit multifamily, other

Households:

- Average household size
- Average number of children
- Percent owner or renter occupied
- Percent headed by a householder who moved in between 1995 and 2000, 1990 to 1994, before 1990

- Percent with incomes under 10, between 10-19, 20-29, 30-39, 40-49, 50-59, 60-74, 75-99, 100-124, 125-154, 150-199, or over 200 thousand dollars; also the average and median household income
- Percent with zero, one, two, three or more vehicles
- Percent headed by a householder who is female/male
- Percent headed by a householder age 15-24, 25-34, 35-44, 45-54, 55-64, 65-74, 75-84, or 85 and up; also average householder age

Population:

- Percent female/male
- Percent white and not Hispanic or another ethnicity
- Percent who are children and who fall into a full range of age brackets; also average and median ages and various ages by gender
- Percent in school or college
- Percent without a high school diploma, with a high school diploma or GED, associate's degree or some college, college degree, graduate degree
- Percent employed (in civilian vs. armed forces jobs), unemployed, or not in the labor force
- Percent in the following industries: retail, restaurants/accommodation, entertainment/recreation, office, education, medical/social service, government, utilities, transportation/warehousing, wholesale, manufacturing, construction, agriculture, extraction, other
- Percent in the following occupations: entertainment, service, office, government, industry

Workers:

- Percent in the following industries: retail, restaurants/accommodation, entertainment/recreation, office, education, medical/social service, public administration, utilities, transportation/warehousing, wholesale, manufacturing, construction, agriculture, extraction, armed forces, other

Census Imputing Methodology

Since census rate variables are applied as multipliers to population, housing, and employment data to derive more specific characteristics, the rate file is used with a number of datasets created by different methodologies. This creates data mismatches, where there are blocks with census rates of zero, but the parcel values in a census block are greater than zero. The effect of applying rates of zero to these variables is the elimination of this data. Therefore, procedures were developed to impute defensible rates for blocks and block groups lacking input data. The following was the methodology used to replace null and zero values in the census dataset using the nearest neighbor approach.

Step 1: Identification of groups of fields that need to be imputed together. Most fields that were processed were imputed as a group of fields due to the fact that a single rate field of zero needs to be assessed with the group of rate fields from which that field is associated. An example of this is the rate fields for population by age category. You may find a census rate for population ages 20 to 24 of zero, but in the same block group, the rate fields for all the other population age fields are greater than zero. The zero in this case reflects data, not the lack of data. Only if all the population age rate fields were zero or null would the model flag a block or block group for imputing.

Step 2: Assigning block or block group ID to fields with null or zero values. For each group of fields and their associated selection of blocks or block groups that contain null or all zero values, the model assigns the block or block group ID (depending on the geography being assessed) from the closest geography centroid that contains values.

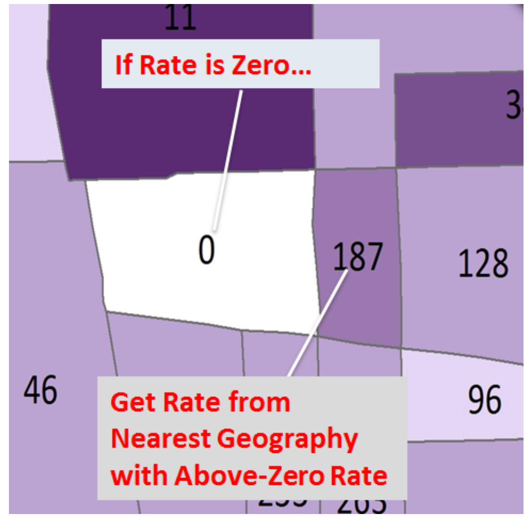


Figure 2-8: Census Imputing Methods

Step 3: Populating null and zero values using nearest neighbor ID. For each near ID assigned to blocks or block groups flagged for imputing, the model populates the null or zero grouping of fields using the associated fields from the block or block group identified as being nearest.

Census Rate Methodology

This section describes the process by which population, housing, and employment rate variables were calculated from block group and block Census, CTPP, and LEHD data.

Census Population and Residential Rate Fields Modeling

All population and housing rate variables were calculated from a combination of Census SF1 (block geography) and SF3 (block group geography) input data. The process involved adding to and calculating a series of rate fields in the block group file. The resulting file was then joined to the block file and a second series of rate fields were added and calculated to derive all final population and housing rates.

In some cases, the final rates were calculated exclusively from either block group or block data (if a data input was available in the block file, that data was used due to its greater geographic specificity). In other cases, data was calculated from a combination of block and block group inputs. The latter approach was used when related input data were available in both the block and block group files, but the block group file provided more disaggregated data. For instance, the block file provides the number of people age 22 to 29, but the block group file subdivides these age ranges into 22 to 24 and 25 to 29. In such cases, block group rates relative to block data were calculated (i.e. the percent of people age 22 to 29 that are 22 to 24). After joining these rates to the block file, the percent of people in these subcategories (i.e. age 22 to 24) could be calculated.

Census Jobs Rate Fields Modeling

All jobs rate variables were calculated from a combination of CTPP (block group geography) and LEHD (block geography) input data. The CTPP dataset is the most comprehensive source for jobs characteristics. Therefore, almost all jobs rate variables were calculated exclusively from CTPP at the block group level and then joined to the block file.

However, LEHD data includes job sector data that, in some cases, are less aggregated than in the CTPP file. For instance, LEHD provides one variable describing the number of jobs in the education sector and another describing the number of jobs in the medical and social service sectors, while CTPP includes only one variable describing the number of in the education, medical, and social service sectors combined. To benefit from this level of disaggregation, the LEHD data was used to calculate a series of secondary rate multipliers to apply to the CTPP block group rates to achieve a more disaggregated set of final rate variables.

Parcels and Grid Loading

The loaded base grid is a primary product of the UrbanFootprint model, combining data from parcel scale modeling with the data inputs from the larger geography reference datasets. The process to create the loaded grid flows from the parcel scale up through a range of spatial and attribute processes to produce a detailed assessment of the base environment at the 150 meter grid cell scale. The following section details the multiple steps in calculating the necessary fields and combining datasets to produce the loaded grid.

Loading Dwelling Units and Employment on Parcels

The parcel-loading step produces the primary population, residential and employment fields modeled at the parcel scale. These fields are the basis from which all other base fields will be derived in the loaded grid. The process to produce the loaded parcel dataset involves distributing population, residential and employment values to individual parcels using land use codes cross-walked to UrbanFootprint building types. These values seed the parcels with data that is then controlled to TAZ control totals. The resulting parcel dataset matches both regional and sub-regional (TAZ) population, residential and employment control totals. Additionally, the loaded parcel dataset provides the parcel land type as well as the acreage use type by primary and sub-use.

Figure 2-9: Applying TAZ Units to Parcels using Land Use Codes

Parcel Load Input Data

The parcel load involves combining a number of processed datasets to calculate the range of fields required by the loaded parcel layer. The input datasets and tables are as follows:

- **Parcel land use data:** A topologically clean parcel layer with roads removed and land use codes joined. This layer should have the original parcel unique ID as well as any empirical data on dwelling unit counts and parcel acreages.
- **Custom Land Use Crosswalk:** This is a custom crosswalk created for each land use code dataset. The crosswalk contains the associated UrbanFootprint building type for each land use code in the dataset. Additionally, the crosswalk identifies whether a land use code is single family or multifamily and where there is a set number of dwelling units per parcel or the number of dwelling units should be modeled. The crosswalk functions as the key for how to allocate units to parcels. All crosswalks used in Vision California are contained in the *Base Data Loading Appendix: Land Use Code Crosswalks* on page A-57.
- **Regional TAZ data:** A topologically clean TAZ layer containing sub-regional control totals for single family and multifamily dwelling units, household average size, occupancy rate and employees by type (retail, office, industrial and agriculture).
- **Land Type dataset:** The statewide Land Type dataset described in the previous Land Type section.

Loaded Parcel Fields

The fields created in the parcel load consist of a range of dwelling unit, employment, acreage by type, and irrigated area fields. The full list of fields is listed in Table 2-3 below.

Table 2-3: Loaded Parcel Fields

Field Name	***Field Definition***
county_luc	Original parcel land use code
acres_parcel	acreage of parcel
landtype	UrbanFootprint land type classification
acres_parcel_urban	acreage of parcel that is urban
acres_parcel_greenfield	acreage of parcel that is greenfield
acres_parcel_constrained	acreage of parcel that is constrained
parcel_sqft	square footage of parcel
building_type_id	cross-walked (from county land use code) building type id
parcel_du	total number of dwelling units
parcel_hh	total number of households
parcel_pop	total population
parcel_du_detsf_sl	number detached single family small lot dwelling units
parcel_du_detsf_ll	number of detached single family large lot dwelling units
parcel_du_mf	number of multifamily dwelling units
parcel_emp	total number of employees
parcel_emp_ret	number of retail employees
parcel_emp_off	number of office employees

Field Name	Field Definition
parcel_emp_ind	number of industrial employees
parcel_emp_ag	number of agricultural employees
acres_parcel_res	total residential acres
acres_parcel_res_detsf	detached single family acres
acres_parcel_res_detsf_sl	detached single family small lot acres
acres_parcel_res_detsf_ll	detached single family large lot acres
acres_parcel_res_mf	multifamily acres
acres_parcel_emp	total commercial acres
acres_parcel_emp_ret	acres with retail employees
acres_parcel_emp_off	acres with office employees
acres_parcel_emp_ind	acres with industrial employees
acres_parcel_emp_ag	acres with agricultural employees
acres_parcel_emp_mixed	acres with more than one type of employee
acres_parcel_mixed	total mixed use acres (with both residential and commercial)
acres_parcel_mixed_w_off	acres with residential units, office employees and retail employees
acres_parcel_mixed_no_off	acres with residential units and retail employees
acres_parcel_no_use	acres with no residential and commercial units
parcel_res_irrigated_sqft	residential irrigated square feet
parcel_emp_irrigated_sqft	commercial irrigated square feet

Seed Data Loading Methodology

For any region, the first step in producing a loaded parcel file is to seed parcels with people, dwelling units by type and employees by type. This is done in a multi-step process utilizing parcel land use codes, a cross-walk of land use codes to UrbanFootprint building types and regional control totals for dwelling units by type and employees by type. The process follows these steps:

Step 1: Assign parcels a land type . The parcel table is intersected with the Land Type seamless dataset and land types are assigned to each parcel based on their centroid.

Step 2: Join land use crosswalk to the parcel file on the Land Use Code: By joining the land use crosswalk, each parcel takes on the rules detailed in the crosswalk table. The rule-based fields in the crosswalk table are listed in Table 2-4**.**

Table 2-4: Land Use Code Crosswalk Fields

Field Name	Field Definition
Land_Use Code	Land use code field
Description	Description of land use code
building_type_id	UrbanFootprint building type ID
du	Number of dwelling units (left blank if no specific number of dwelling units is known)
minimum_du	Minimum number of dwelling units on a parcel
maximum_du	Maximum number of dwelling units on a parcel
sf_flag	Boolean flag if land use code is single family
mf_flag	Boolean flag if land use code is multifamily

du_iterate_flag	Boolean flag if process should model the number of dwelling units base of parcel area

Step 3: Calculating constants for modeling dwelling units and employment by type. Once the land use crosswalk has been joined to the parcel table, each parcel knows whether it will have single family or multifamily dwelling units and whether it will have retail, office, industrial or agricultural jobs on it (from the building type). To model the number of jobs and dwelling units on parcels, densities are applied to parcel acres, based on the assumption that quantities vary by parcel size. Constants control the magnitude of these densities and thus are calculated before modeling. In this way, when densities are applied, all modeled units and employees will sum to control totals. The general equation for modeling the constants for each dwelling unit type and employment type is Equation 2-2**.**

Equation 2-2: Deriving constants for scenario control totals

$$c_T = \frac{t_T}{\sqrt{A_T}}$$

Where:
c_T = Constant for type T of employment or dwelling units
A_T = Sum of all acres of type T of employment or dwelling units that are flagged to be modeled
t_T = Control total for type T employment or dwelling units

Step 4: Modeling dwelling unit process: The parcel load process first assumes that a dwelling unit count (even partial) is contained in the parcel table and assigns those values as a first pass. For the next pass, the model assigns dwelling unit counts to parcels containing no dwelling unit count in the parcel table using the quantities specified in the building type crosswalk, which is assigned by land use. For the remaining parcels flagged as residential, the model then derives the number of units based on the area of the parcel and whether it was flagged as single family or multifamily. The equation for modeling dwelling units by parcel area is specified in Equation 2-3**.**

Equation 2-3: Deriving units using parcel area and density assumptions

$$DU_T = c_T * \sqrt{a_p}$$

Where:
DU_T = The number of dwelling units of type T (single family or multifamily)
c_T = The constant associated with dwelling unit of type T
a_p = The acres of a given parcel

Step 5: Classifying residential parcels into UrbanFootprint building types. As part of the land use crosswalk, each residential parcel knows whether it is single family or multifamily and from the previous step, it knows how many dwelling units it has. To classify residential parcels to building types, the model assigns building types to parcels using dwelling unit density ranges for single family and multifamily types. The building types and their associated densities are contained in Table 2-5**.**

Table 2-5: Residential Classification by Building Type

Building Type ID	Building Type Description	Dwelling Unit Type	DU/Acre Low	DU/Acre High	Sqft/DU Low	Sqft/DU High
8	Skyscraper Residential	Multifamily	400	> 400		
9	Skyscraper Residential	Multifamily	250	400		
10	Urban Mid-Rise Residential	Multifamily	150	250		
11	Multi-Family Apt/Condo	Multifamily	75	150		
12	Multi-Family Apt/Condo	Multifamily	50	75		
13	Multi-Family Apt/Condo	Multifamily	30	50		
16	Townhome	Multifamily	0	30		
17	Small Lot Residential	Single Family			0	3500
18	Small Lot Residential	Single Family			3500	4500
19	Medium Lot Residential	Single Family			4500	6000
20	Large Lot Residential	Single Family			6000	9000
21	Large Lot Residential	Single Family			9000	25000
22	Rural Residential	Single Family			25000	100000
23	Rural Residential	Single Family			100000	> 100000

Step 6: Classifying single-family dwelling units into small and large lot. At this step each parcel already knows the type of dwelling units it has, its associated building type and whether it's single family or multifamily. The final step is to classify all single-family units into small or large lots. A simple break point is used for this. Any single family parcel with square feet per dwelling unit less than 5,500 is considered small lot and any single family parcels above this threshold are considered large lot.

Step 7: Modeling employees by type. Employees are modeled on parcels using acreage densities informed by derived constants, each associated with the four major employment categories of retail, office, industrial and agriculture referenced in step 3. Parcels are flagged to take units from the different employment types based on their associated building type and the percent of each employment type within that building type. The equation for deriving employment totals for a given employment type can be seen in Equation 2-4**.**

Equation 2-4: Deriving employment by type using parcel area and density assumptions

$$Emp_T = c_T * p_T * \sqrt{A}$$

Where:

Emp_T = number of employees of type T

p_T = percent of building type that is employment type T

c_T = constant for employees of type T

A = parcel acreage

Final Table from Seed Data Loading. The output table from the seed data loading process contains dwelling units on parcels by single family and multifamily types that match regional control totals for those fields. The table also contains employment fields at the parcel scale for the high level categories of retail, office, industrial, and agriculture, all of which match regional control totals. This table is the primary input to the TAZ controlling process.

TAZ Controlling Methodology

The TAZ controlling process is applied to the parcel table loaded with seed data to ensure that TAZ scale distributions of units are mirrored in the final loaded parcel table. That means that the aggregation of parcel units within any given TAZ, whether dwelling units by type or employment by type, will always match the TAZ values for those units. For the parcel load, the TAZ table is considered the primary table for controlling both the quantity of units by type and the spatial distribution of those units at an aggregate scale. The TAZ controlling method follows a number of rule-based operations to reallocate both quantities of units and the spatial distribution of some units. These rule-based processes are detailed in this section.

Step 1: Parcel layer is intersected with the TAZ layer. To identify which TAZ each parcel belongs, the TAZ file is spatially joined to parcel centroids, with each parcel taking on the TAZ ID they intersect with.

Step 2: First pass, all parcel values summed to TAZ scale, TAZ and parcel difference rates derived and difference rates applied to parcels. The first pass of the TAZ controlling process takes a first cut at matching parcel aggregations of the fields listed in Table 2-6 to their associated TAZ control totals. For each field, the process first sums the values in the parcel table to the TAZ scale, and then divides the TAZ control total by the parcel aggregated total. This derives the rate or percent difference between the parcel total and the control total. These TAZ rates are then multiplied back to the parcels in order to alter the existing parcel values up or down. This first pass only alters the quantities of dwelling units or employees by type in parcels that already have units.

Table 2-6: Fields for TAZ Controlling

Field Name	*Field Definition*
du_detsf	number of detached single family units
du_mf	number of multifamily units
emp_ret	number of retail employees
emp_off	number of office employees
emp_ind	number of industrial employees
emp_ag	number of agricultural workers

Step 3: Pass two, allocation of values to parcels which have no associated dwelling units or employment of types which TAZs contain. This second pass looks only at TAZs which *have* dwelling units or employment by type and do not contain parcels with those units. The rule for this pass assumes that certain building types or acreage types, which are not classified to take dwelling units or employment of different types, could feasibly take units of specific types. For example, the building type 'Main Street Commercial' does not by definition take multifamily units, but in this pass it is allowed to take multifamily dwelling units. The fields which are allowed to fall on select building types and acreage

types in this pass are listed in Table 2-7. For each of these combinations, the acreage of the parcels associated with the building or acreage types are summed to the TAZ and then used to derive rates. The rate is calculated as the TAZ control total divided by acreage total for each building and acreage combination. This rate is then multiplied back to the acres of parcels which contain those building types or acreage types within the select TAZs.

Table 2-7: Dwelling Unit and Employment fields assigned to alternate building or acreage types

Field Name	*Building Type Id/Acreage Type*	*Description*
Detached Single Family		
	60	*Military General Catch-All*
	Acres_greenfield	*greenfield acres (land types)*
Multifamily		
	28	*Main Street Commercial*
	31	*Office Park High*
	32	*Office Park Low*
	40	*Medium Intensity Strip Commercial*
	41	*Low Intensity Strip Commercial*
	44	*Campus/College*
	55	*Urban Convention Center*
Retail Employment		
	32	*Office Park Low*
	33	*Industrial High*
	34	*Industrial Low*
	35	*Warehouse High*
	36	*Warehouse Low*
Office Employment		
	4	*Low-Rise Mixed*
	5	*Parking Structure/Mixed Use*
	7	*Main Street Commercial/MU Low*
	8	*Skyscraper Residential*
	9	*High-Rise Residential*
	11	*Urban Podium Multi-Family*
	13	*Suburban Multifamily Apt/Condo*
	30	*Parking Structure*
	34	*Industrial Low*
	38	*Hotel Low*
	41	*Low Intensity Strip Commercial*
Industrial Employment		
	4	*Low-Rise Mixed*
	5	*Parking Structure/Mixed Use*
	6	*Main Street Commercial/MU High*

Field Name	Building Type Id/Acreage Type	Description
	7	Main Street Commercial/MU Low
	8	Skyscraper Residential
	9	High-Rise Residential
	26	Mid-Rise Office
	27	Low-Rise Office
	29	Parking Structure+Ground-Floor Retail
	31	Office Park High
	32	Office Park Low
	40	Medium Intensity Strip Commercial
	41	Low Intensity Strip Commercial
	43	University
	44	Campus/College
	45	Hospital
	55	Urban Convention Center
	56	Civic/Institutional
Agriculture Employment		
	43	University
	44	Campus/College
	46	Elementary School Urban
	47	Elementary School Suburban
	49	Middle School Suburban
	51	High School Suburban
	60	Military General Catch-All

Step 4: Allocation of remaining units to Urban Acres. For TAZs that still have units but no parcels to take those units, this pass places units on land typed 'Urban' parcels. The process first sums 'Urban' parcels acres to the TAZ scale and then the TAZ control total is divided by the aggregated urban parcel acreage to derive the rate. These rates are then applied to the parcels with 'Urban' acres in order to allocate the units. This pass should capture most of the remaining TAZs that have units, but do not have parcels to take those units.

Step 5: Allocation of remaining units to All Acres. For all remaining TAZs that still have units and no parcels to take those units, all units are distributed evenly to the parcels based on parcels acreage. This done by aggregating all parcel acres to the TAZ scale and then dividing the TAZ control total by this aggregated acreage to derive the rate. The rates are then applied back to all parcel acres in the TAZ to allocate the units. This is the final pass and at this point, TAZ control totals are mirrored in parcel totals.

Step 6: Calculating population and household fields. Households and population are derived by applying TAZ scale rates to parcel scale dwelling unit totals. The first pass models parcel households by multiplying that TAZ scale occupancy rate by the parcel level dwelling units. The second pass models parcel population by multiplying TAZ scale household average size by the parcel households derived in the first pass. This produces both population and households on each parcel informed both by TAZ level data and parcels scale modeling.

Step 7: Calculating irrigated area for residential and employment parcels. The final step in the TAZ loading process is to calculate the irrigated square footage for residential and commercial parcels. This process calculates irrigated area using building type attributes. Each building type has a density for residential and commercial irrigated square feet per acre. These irrigated area densities are calculated as part of the building type creation process using empirical data. This data provides each building type with a use percent (either residential or commercial), building type parcel hardscape area and the percent of soft scape area that is irrigated. The equation for building type irrigated area density can be reference in Equation 2-5**.**

Equation 2-5: Residential or Commercial Irrigated Square Feet / Acre density

$$Irr_{sqft} = Ac_a * U_{pct} * \left(1 - H_{pct}\right) * Irr_{pct} * 43560$$

Where:

$Irr_{sqft} = Irrigated\ square\ feet\ per\ acre$

$Ac_a = Assumed\ parcel\ area\ associate\ with\ building\ type\ a$

$U_{pct} = Parcel\ use\ percent\ (either\ residential\ or\ commercial\ uses$

$H_{pct} = Hardscape\ percent\ of\ assumed\ parcel\ area$

$Irr_{pct} = Percent\ of\ non - hardscape\ area\ that\ is\ irrigated$

As most parcels with units (either dwelling units or employees or both) contain a building type, the building type attributes for irrigated area are joined to the parcel table on the building type field. As a first pass, the irrigated square feet for residential and commercial parcels are calculated from the building type densities. Due to the TAZ controlling process, parcel attributes may not correspond with their building type and some parcels which contain units may not have a building type. For these cases, the model checks parcels with building types to see if there are associated dwelling units on residential parcels and employees on commercial parcels. If there are no units on parcels with building types, the model removes the associated irrigated area.

For all other parcels, which have units but no building types, the model uses average rates to calculate irrigated area. For residential parcels with no building types but have dwelling units, the model assumes that 15% of the parcel area would be irrigated. For commercial acres with no building type, the model assumes 6000 square feet per acre is irrigated. In addition, due to the variation in parcel size and some inaccuracies in classifying the dataset into building types, the model applies maximum irrigated areas constraints for commercial and residential parcels respectively. For residential parcels, the maximum irrigated area allowed is 20,000 square feet and for commercial parcels, the maximum irrigated area is 100,000 square feet. These maximum values are adjustable in the model to allow the user to match regional per household and per employee control totals.

Loaded TAZ-Controlled Parcel Table

The loaded TAZ-controlled parcel table is the final data product of the parcel load process. It contains the fields listed in Table 2-3**;** the primary dwelling unit and employment fields mirror TAZ aggregate totals and distributions. The loaded TAZ-controlled parcel table is one of the primary inputs into the grid load process and contains the fields to which census rates will be applied and derivative fields generated.

Loaded Base Grid with Parcel and Census Demographic Data

The final step in the base data creation process is to bring together parcel-scale data, census rate data and walkable intersection data with the 150 meter grid to produce the loaded base grid. This is a multi-step process which includes a number of geometric intersections of datasets and attribute calculations. The process to produce the loaded base grid is detailed in this section.

Loaded Base Grid Input Data

The following datasets are combined and used in the grid load process, each providing different geography and attribute fields to the final loaded base grid.

- **150-meter grid table:** A topologically clean, full coverage 150 meter grid of the study region
- **Loaded TAZ-controlled parcel table:** The loaded parcel table created through the seed data loading and TAZ controlling process.
- **Census rate table:** The statewide block scale census rates described in the previous Census Rate Dataset section.
- **Land type reference table:** The statewide land type dataset described in the previous Land Type Data section.
- **Intersection density reference table:** The statewide intersection density dataset described in the previous Walkable Street Intersection Data section

Loaded Base Grid Fields

The base grid loading process produces a wide range of fields including detailed population characteristics, household characteristics, detailed employment breakdowns and building characteristics. Table 2-8 provides the full listing of fields in the loaded grid table.

Table 2-8: Loaded Base Grid Fields

Variable Name	*Definition*
ID_Grid	*Grid ID*
County	*County Name*
UrbanFootprint Land Development Codes	
Placetype_ID	*Place type code*
Urban_LDC	*Urban Land Development Category grid cell flag (Boolean)*
Compact_LDC	*Compact Land Development Category grid cell flag (Boolean)*
Standard_LDC	*Standard Land Development Category grid cell flag (Boolean)*
Area Variables by Use and Landtype	

Variable Name	*Definition*
Parcel_SqFt	*Parcel square feet*
Acres_Grid	*Grid cell acres (approx. 5.55987)*
Acres_Grid_Urban	*Urban grid cell acres*
Acres_Grid_GF	*Greenfield grid field acres*
Acres_Grid_Con	*Constrained grid field acres*
Acres_Parcel	*Parcel acres*
Acres_Parcel_Urban	*Urban parcel acres*
Acres_Parcel_GF	*Greenfield parcel acres*
Acres_Parcel_Con	*Constrained parcel acres*
Acres_Parcel_Res	*Parcel acres with dwelling units **exclusively***
Acres_Parcel_Res_DetSF	*Parcel acres with detached single family dwelling units (**not exclusive:** could have commercial or other residential types)*
Acres_Parcel_Res_DetSF_SL	*Parcel acres with small lot detached single family dwelling units (< 5500 sq. ft.) (**not exclusive:** could have commercial or other residential types)*
Acres_Parcel_Res_DetSF_LL	*Parcel acres with large lot detached single family dwelling units (> 5500 sq. ft.) (**not exclusive:** could have commercial or other residential types)*
Acres_Parcel_Res_MF	*Parcel acres with multi-family dwelling units (**not exclusive:** could have commercial or other residential types)*
Acres_Parcel_Emp	*Parcel acres with jobs **exclusively***
Acres_Parcel_Emp_Off	*Parcel acres with office jobs (**not exclusive:** could have residential or other commercial types)*
Acres_Parcel_Emp_Ret	*Parcel acres with retail jobs (**not exclusive:** could have residential or other commercial types)*
Acres_Parcel_Emp_Ind	*Parcel acres with industrial jobs (**not exclusive:** could have residential or other commercial types)*
Acres_Parcel_Emp_Ag	*Parcel acres with agricultural jobs (**not exclusive:** could have residential or other commercial types)*
Acres_Parcel_Emp_Mixed	*Parcel acres with more than one job type (**not exclusive:** could also have residential)*
Acres_Parcel_Mixed	*Parcel acres with **both** dwelling units and jobs*
Acres_Parcel_Mixed_w_Off	*Parcel acres with both dwelling units and retail and office jobs (**not exclusive:** could have other commercial types)*
Acres_Parcel_Mixed_no_Off	*Parcel acres with both dwelling units and retail jobs (**not exclusive:** could have other commercial types, but will not include office)*
Acres_Parcel_No_Use	*Parcel acres with **neither** dwelling units or jobs*
Acres_Parcel_Urban_Res	*Urban parcel acres with dwelling units **exclusively***
Acres_Parcel_Urban_Emp	*Urban parcel acres with jobs **exclusively***
Acres_Parcel_Urban_Mixed	*Urban parcel acres with **both** dwelling units and jobs*
Acres_Parcel_Urban_No_Use	*Urban parcel acres with **neither** dwelling units or jobs*
Acres_Parcel_GF_Res	*Greenfield parcel acres with dwelling units **exclusively***
Acres_Parcel_GF_Emp	*Greenfield parcel acres with jobs **exclusively***
Acres_Parcel_GF_Mixed	*Greenfield parcel acres with **both** dwelling units and jobs*
Acres_Parcel_GF_No_Use	*Greenfield parcel acres with **neither** dwelling units or jobs*
Acres_Parcel_Con_Res	*Constrained parcel acres with dwelling units **exclusively***
Acres_Parcel_Con_Emp	*Constrained parcel acres with jobs **exclusively***

Variable Name	*Definition*
Acres_Parcel_Con_Mixed	*Constrained parcel acres with **both** dwelling units and jobs*
Acres_Parcel_Con_No_Use	*Constrained parcel acres with **neither** dwelling units or jobs*
Emp_Irrigated_SqFt	*Commercial irrigated parcel square feet*
Res_Irrigated_SqFt	*Residential irrigated parcel square feet*
Density Variables	
Gross_DU_Dens	*Dwelling units per grid cell acre*
Gross_HH_Dens	*Households per grid cell acre*
Gross_Pop_Dens	*Population per grid cell acre*
Gross_Emp_Dens	*Jobs per grid cell acre*
Gross_Tot_Dens	*Population plus jobs per grid cell acre*
Net_DU_Dens	*Dwelling units per parcel acre*
Net_HH_Dens	*Households per parcel acre*
Net_Pop_Dens	*Population per parcel acre*
Net_Emp_Dens	*Jobs per parcel acre*
Net_Tot_Dens	*Population plus jobs per parcel acre*
Use_DU_Dens	*Dwelling units per residential and mixed use acre*
Use_HH_Dens	*Households per residential and mixed use acre*
Use_Pop_Dens	*Population per residential and mixed use acre*
Use_Emp_Dens	*Jobs per grid employment and mixed use acre*
Dwelling Unit Variables	
DU	***Number** of dwelling units*
DU_DetSF	***Number** of detached single family dwelling units*
DU_DetSF_SL	***Number** of small lot (under 5500 sq. ft.) detached single family dwelling units (includes mobile home lots)*
DU_DetSF_LL	***Number** of large lot (5500 sq. ft. or more) detached single family dwelling units*
DU_AttSF	***Number** of attached single family dwelling units*
DU_MF2to4	***Number** of dwelling units in multifamily buildings with 2-4 units*
DU_MF5p	***Number** of dwelling units in multifamily buildings with 5 units and more*
DU_MF	***Number** of dwelling units in multifamily buildings*
DU_Occ_Rate	***Occupancy Rate***
Household Variables	
HH	***Number** of households*
HH_Avg_Size	***Average** number of people per household*
HH_Avg_Children	***Average** number of children (under 18) per household*
HH_Own_Occ	***Number** of households that are owner occupied*
HH_Rent_Occ	***Number** of households that are renter occupied*
HH_Own_Occ_Pct	***Percent** of households that are owner occupied*
HH_Rent_Occ_Pct	***Percent** of households that are renter occupied*
HH_Inc_00_10	***Number** of households with income under $10,000*
HH_Inc_10_20	***Number** of households with income between $10,000-19,999*

Variable Name	*Definition*
HH_Inc_20_30	***Number** of households with income between $20,000-29,999*
HH_Inc_30_40	***Number** of households with income between $30,000-39,999*
HH_Inc_40_50	***Number** of households with income between $40,000-49,999*
HH_Inc_00_50	*The sum of HH_Inc_00_10, HH_Inc_10_20, HH_Inc_20_30, HH_Inc_30_40, and HH_Inc_40_50*
HH_Inc_50_60	***Number** of households with income between $50,000-59,999*
HH_Inc_60_75	***Number** of households with income between $60,000-74,999*
HH_Inc_50_75	*The sum of HH_Inc_50_60 and HH_Inc_60_75*
HH_Inc_75_100	***Number** of households with income between $75,000-99,999*
HH_Inc_100p	*The sum of HH_Inc_100_125, HH_Inc_125_150, HH_Inc_150_200, and HH_Inc_200p*
HH_Inc_100_125	***Number** of households with income between $100,000-124,999*
HH_Inc_125_150	***Number** of households with income between $125,000-149,999*
HH_Inc_150_200	***Number** of households with income between $150,000-199,999*
HH_Inc_200p	***Number** of households with income $200,000 and up*
HH_Inc_00_10_Pct	***Percent** of households with income under $10,000*
HH_Inc_10_20_Pct	***Percent** of households with income between $10,000-19,999*
HH_Inc_20_30_Pct	***Percent** of households with income between $20,000-29,999*
HH_Inc_30_40_Pct	***Percent** of households with income between $30,000-39,999*
HH_Inc_40_50_Pct	***Percent** of households with income between $40,000-49,999*
HH_Inc_50_60_Pct	***Percent** of households with income between $50,000-59,999*
HH_Inc_60_75_Pct	***Percent** of households with income between $60,000-74,999*
HH_Inc_75_100_Pct	***Percent** of households with income between $75,000-99,999*
HH_Inc_100p_Pct	***Percent** of households with income $100,000 and up*
HH_Inc_100_125_Pct	***Percent** of households with income between $100,000-124,999*
HH_Inc_125_150_Pct	***Percent** of households with income between $125,000-149,999*
HH_Inc_150_200_Pct	***Percent** of households with income between $150,000-199,999*
HH_Inc_200p_Pct	***Percent** of households with income $200,000 and up*
HH_Avg_Inc	***Average** household income*
HH_Agg_Inc	***Total** (aggregate) income for grid cell*
HH_Veh0	***Number** of households with no vehicles*
HH_Veh1	***Number** of one vehicle households*
HH_Veh2	***Number** of two vehicle households*
HH_Veh3p	***Number** of three or more vehicle households*
HH_Avg_Veh	***Average** number of vehicles per household*
HH_Agg_Veh	***Number** of household vehicles for grid cell*
Population Variables	
Pop	*Residential Population (not in group quarters)*
Pop_Female	***Number** of people who are female*
Pop_Male	***Number** of people who are male*
Pop_Female_Pct	***Percent** of population who is female*

Variable Name	*Definition*
Pop_Male_Pct	***Percent*** *of population who is male*
Pop_White_Not_Hisp	***Number*** *of people who are white and not Hispanic/Latino*
Pop_of_Color	***Number*** *of people who are people of color (non-white race nor Hispanic/Latino)*
Pop_White_Not_Hisp_Pct	***Percent*** *of population who is white and not Hispanic/Latino*
Pop_of_Color_Pct	***Percent*** *of population who is a person of color (non-white race nor Hispanic/Latino)*
Pop_Children	***Percent*** *of population under 18 years old*
Pop_Age0_4	***Number*** *of people under 5 years old*
Pop_Age5_9	***Number*** *of people age 5-9*
Pop_Age10_14	***Number*** *of people age 10-14*
Pop_Age15_17	***Number*** *of people age 15-17*
Pop_Age18_19	***Number*** *of people age 18-19*
Pop_Age20	***Number*** *of people age 20*
Pop_Age21	***Number*** *of people age 21*
Pop_Age22_24	***Number*** *of people age 22-24*
Pop_Age25_29	***Number*** *of people age 25-29*
Pop_Age30_39	***Number*** *of people age 30-39*
Pop_Age40_49	***Number*** *of people age 40-49*
Pop_Age50_64	***Number*** *of people age 50-64*
Pop_Age65_Up	***Number*** *of people age 65 and up*
Pop_Age16_Up	***Number*** *of people age 16 and up*
Pop_Age25_Up	***Number*** *of people age 25 and up*
Pop_Avg_Age	***Average*** *age of the population*
Pop_Avg_Age_of20_64	***Average*** *age of the population that is 20-64*
Pop_Avg_Age_of25_64	***Average*** *age of the population that is 25-64*
Pop_Avg_Age_of20_up	***Average*** *age of the population that is 20 and up*
Pop_Avg_Age_of25_up	***Average*** *age of the population that is 25 and up*
Pop_Female_Age20_64	***Number*** *of people who are female and age 20-64*
Pop_Male_Age20_64	***Number*** *of people who are male and age 20-64*
Pop_Female_Age25_64	***Number*** *of people who are female and age 25-64*
Pop_Male_Age25_64	***Number*** *of people who are male and age 25-64*
Pop_Female_of_Age20_64_pct	***Percent*** *of population age 20-64 who are female*
Pop_Male_of_Age20_64_pct	***Percent*** *of population age 20-64 who are male*
Pop_in_School	***Number*** *of people in preschool, kindergarten, or grades 1-12*
Pop_in_College	***Number*** *of people in college (undergrad, grad or prof)*
Pop_HS_Not_Comp	***Number*** *of people who did not finish high school*
Pop_HS_Diploma	***Number*** *of people who graduated high school/GED*
Pop_Assoc_Some_Coll	***Number*** *of people with some college education or an associate's degree*
Pop_Coll_Degree	***Number*** *of people who graduated college*
Pop_Grad_Degree	***Number*** *of people with post-college degrees*

Variable Name	*Definition*
Pop_HS_Not_Comp_Pct	***Percent*** *of population who did not finish high school*
Pop_HS_Diploma_Pct	***Percent*** *of population who graduated high school/GED*
Pop_Assoc_Some_Coll_Pct	***Percent*** *of population with some college education or an associate's degree*
Pop_Coll_Degree_Pct	***Percent*** *of population who graduated college*
Pop_Grad_Degree_Pct	***Percent*** *of population with post-college degrees*
Pop_Employed	***Number*** *of employed residents*
Pop_Employed_Civ	***Number*** *of civilian employed residents*
Pop_Employed_AF	***Number*** *of armed forces employed residents*
Pop_Unemployed	***Number*** *of unemployed residents*
Pop_Not_in_LaborForce	***Number*** *of people not in the labor force*
Pop_Ind_Retail	***Number*** *of people in the retail industry*
Pop_Ind_RestAccom	***Number*** *of employed residents in the restaurant and hotel industry*
Pop_Ind_EntRec	***Number*** *of employed residents in the arts, entertainment, and recreation industries*
Pop_Ind_Office	***Number*** *of people in the office industry (professional, administrative)*
Pop_Ind_Educ	***Number*** *of employed residents in the education industry*
Pop_Ind_MedSS	***Number*** *of employed residents in the health and social services industry*
Pop_Ind_Public	***Number*** *of people in the public administration industry (not including armed forces)*
Pop_Ind_Manuf	***Number*** *of employed residents in the manufacturing industry*
Pop_Ind_TransWare	***Number*** *of employed residents in the transportation and warehousing industry*
Pop_Ind_Util	***Number*** *of employed residents in the utilities industry*
Pop_Ind_Whole	***Number*** *of employed residents in the wholesale industry*
Pop_Ind_Constr	***Number*** *of employed residents in the construction industry*
Pop_Ind_Other	***Number*** *of employed residents in the repair services (auto, furniture, electronic), laundry, funeral, and not-for-profit (foundations, advocacy, unions, churches) industries*
Pop_Ind_Ag	***Number*** *of employed residents in the farming, forestry, fishing, hunting, and fishing industries*
Pop_Ind_Extract	***Number*** *of employed residents in the oil and mining industry*
Job Variables	
Emp	***Number*** *of jobs (workers at work)*
Emp_Retail	***Number*** *of retail jobs*
Emp_RestAccom	***Number*** *of restaurant, food service, and accommodation jobs*
Emp_EntRec	***Number*** *of arts, entertainment, and recreation jobs*
Emp_Office	***Number*** *of office jobs*
Emp_Public	***Number*** *of public jobs*
Emp_AF	***Number*** *of armed forces jobs*
Emp_Educ	***Number*** *of education jobs*
Emp_MedSS	***Number*** *of health care and social service jobs*
Emp_TransWare	***Number*** *of transportation and warehousing jobs*

Variable Name	*Definition*
Emp_Whole	***Number** of wholesale jobs*
Emp_Manuf	***Number** of manufacturing jobs*
Emp_Util	***Number** of utility jobs*
Emp_Constr	***Number** of construction jobs*
Emp_Other	***Number** of repair (auto, electronic, furniture, etc.), laundromat, funeral home, and nonprofit (churches, advocacy groups, unions, foundations, etc.) jobs*
Emp_Ag	***Number** of agriculture, forestry, fishing, and hunting jobs*
Emp_Extract	***Number** of oil and mining jobs*
Emp_VMT_Office	*The sum of Emp_Office, Emp_MedSS, and Emp_AF (for purposes of the VMT engine)*
Emp_VMT_Public	*The sum of Emp_Public and Emp_Educ (for purposes of the VMT engine)*
Emp_Industry	*The sum of Emp_Manuf, Emp_TransWare, Emp_Util, Emp_Whole, Emp_Constr, Emp_Other, Emp_Ag, and Emp_Extract (for purposes of the VMT engine)*
Emp_Industry_No_Ag	*The same as Emp_Industry, except Emp_Ag and Emp_Extract are excluded.*
Building Square Footage Variables	
Bldg_SqFt_DetSF	*Number of detached single family housing building square feet*
Bldg_SqFt_DetSF_SL	*Number of small lot detached single family housing building square feet*
Bldg_SqFt_DetSF_LL	*Number of large lot detached single family housing building square feet*
Bldg_SqFt_AttSF	*Number of attached single family housing building square feet*
Bldg_SqFt_MF2to4	*Number of 2-4 unit multifamily housing building square feet*
Bldg_SqFt_MF5p	*Number of 5-plus unit multifamily housing building square feet*
Bldg_SqFt_Retail	*Number of retail building square feet*
Bldg_SqFt_RestAccom	*Number of restaurant, food service, and hotel building square feet*
Bldg_SqFt_EntRec	*Number of arts, entertainment, and recreation building square feet*
Bldg_SqFt_Emp_Other	*Number of other building square feet (includes repair, laundry, funeral services, and nonprofit office buildings)*
Bldg_SqFt_Office	*Number of office building square feet*
Bldg_SqFt_Public	*Number of public building square feet*
Bldg_SqFt_AF	*Number of armed forces building square feet*
Bldg_SqFt_Educ	*Number of education building square feet*
Bldg_SqFt_MedSS	*Number of health care and social service building square feet*
Bldg_SqFt_TransWare	*Number of transportation and warehousing building square feet*
Bldg_SqFt_Whole	*Number of wholesale building square feet*
Bldg_SqFt_Manuf	*Number of manufacturing building square feet*
Bldg_SqFt_Util	*Number of utility building square feet*
Bldg_SqFt_Constr	*Number of construction building square feet*
Street Intersections	
Intersections	*Number of Intersections within a grid cell*
Intersection_Density_SqMi	*Intersections per square mile (calculated using a quarter mile radius from grid cell)*
Intersection_Density_SqKm	*Intersections per square kilometer (calculated using a one kilometer radius from*

Variable Name	*Definition*
	grid cell)
Intersection_Count_QtrMi	*Intersections within a one quarter mile radius of the grid cell*
Intersection_Count_OneKm	*Intersections within a one kilometer radius of the grid cell*

Census, Demographic and Building Square Feet Loading Methodology

To produce the wide range of fields contained in the loaded base grid, the model jumps through a number of intermediate steps, producing temporary tables reflecting geographic operations and intermediate calculations. The process is computationally intensive, merging regional parcel data with census blocks and the UrbanFootprint 150-meter grid. The details of the methodology are contained in the following section.

Step 1: Intersect loaded parcel table with the 150 meter grid. This first step creates a parcel portions table that is the result of intersecting the parcel table with the 150-meter grid. This process 'cookie cutters' the parcel geometry using the grid geometry, creating what is referred to as parcel portions. The area of each portion is then calculated and divided by each parcel portion's original parcel total area, producing the percent of parcel area that each portion represents. This will be used to distribute units to parcel portions at a later step. Additionally, each parcel portion is populated with a field containing the Grid ID, which will later be used to aggregate parcel portions to the grid geometry.

Step 2: Distribute parcel units to parcel portions using proportional area. The base load model assumes that units contained in the loaded parcel table are equally distributed across parcel area. Using this logic, the units contained in parcels are distributed to parcel portions using the parcel portion percent of parcel area field calculated in the previous step. This calculation for distributing units can be seen in Equation 2-6.

Equation 2-6: Distributing units to parcel portions

$$F_{pp} = P_{pp} * F_p$$

$F_{pp} = Value\ of\ field\ F\ on\ parcel\ portion$

$P_{pp} = Parcel\ portio\ percent\ of\ parcel\ area$

$F_p = Value\ of\ field\ F\ on\ parcel$

Step 3: Intersect parcel portions with census blocks. Having distributed loaded parcel units to the parcel portions, the next step is to assign each parcel portion to a block ID. This is done by assigning the block ID to parcel portions where the parcel portion centroid intersects the block geography.

Step 4: Join Census Rate table to parcel portions on block ID and apply census rates to parcel portions. Having assigned a block ID to each parcel portion based on geography, the Census Rates table is joined to the parcel portions table on the Block ID. The census rates are used to split the primary parcel fields from the processed parcel portion table into the detailed population characteristics, household characteristics and detailed employment breakdowns. Equation 2-7 represents the process for splitting primary fields to detailed census fields.

Equation 2-7: Census rate application to parcel fields

$$Fd_{pp} = Cr_d * F_p$$

$Fd_{pp} = Derivative\ loaded\ grid\ field$

$Cr_d \ = Census\ rate\ for\ dervitave\ grid\ field$

$F_p \ = Loaded\ parcel\ field$

The list of fields from the loaded parcel table contained in the parcel portion table and the fields to which they are distributed to using the census rates table are listed in Table 2-9.

Table 2-9: Parcel Fields and Derivative Grid Fields Created by Census Rates

Loaded Parcel Fields	*Derivative Loaded Grid Fields*	*Derivative Field Description*
Multifamily Dwelling Units		
Parcel_DU_MF	DU_MF2to4	***Number*** *of dwelling units in multifamily buildings with 2-4 units*
Parcel_DU_MF	DU_MF5p	***Number*** *of dwelling units in multifamily buildings with 5 units and more*
Household Tenure		
Parcel_HH	HH_Own_Occ	***Number*** *of households that are owner occupied*
Parcel_HH	HH_Rent_Occ	***Number*** *of households that are renter occupied*
Household Income		
Parcel_HH	HH_Inc_00_10	***Number*** *of households with income under $10,000*
Parcel_HH	HH_Inc_10_20	***Number*** *of households with income between $10,000-19,999*
Parcel_HH	HH_Inc_20_30	***Number*** *of households with income between $20,000-29,999*
Parcel_HH	HH_Inc_30_40	***Number*** *of households with income between $30,000-39,999*
Parcel_HH	HH_Inc_40_50	***Number*** *of households with income between $40,000-49,999*
Parcel_HH	HH_Inc_50_60	***Number*** *of households with income between $50,000-59,999*
Parcel_HH	HH_Inc_60_75	***Number*** *of households with income between $60,000-74,999*
Parcel_HH	HH_Inc_50_75	*The sum of HH_Inc_50_60 and HH_Inc_60_75*
Parcel_HH	HH_Inc_75_100	***Number*** *of households with income between $75,000-99,999*
Parcel_HH	HH_Inc_100p	*The sum of HH_Inc_100_125, HH_Inc_125_150, HH_Inc_150_200, and HH_Inc_200p*
Parcel_HH	HH_Inc_100_125	***Number*** *of households with income between $100,000-124,999*

Loaded Parcel Fields	*Derivative Loaded Grid Fields*	*Derivative Field Description*
Parcel_HH	HH_Inc_125_150	***Number*** *of households with income between $125,000-149,999*
Parcel_HH	HH_Inc_150_200	***Number*** *of households with income between $150,000-199,999*
Parcel_HH	HH_Inc_200p	***Number*** *of households with income $200,000 and up*
Household Vehicle Ownership		
Parcel_HH	HH_Veh0	***Number*** *of households with no vehicles*
Parcel_HH	HH_Veh1	***Number*** *of one vehicle households*
Parcel_HH	HH_Veh2	***Number*** *of two vehicle households*
Parcel_HH	HH_Veh3p	***Number*** *of three or more vehicle households*
Population by Gender		
Parcel_Pop	Pop_Female	***Number*** *of people who are female*
Parcel_Pop	Pop_Male	***Number*** *of people who are male*
Population by Race		
Parcel_Pop	Pop_White_Not_Hisp	***Number*** *of people who are white and not Hispanic/Latino*
Parcel_Pop	Pop_of_Color	***Number*** *of people who are people of color (non-white race nor Hispanic/Latino)*
Population by Age		
Parcel_Pop	Pop_Age0_4	***Number*** *of people under 5 years old*
Parcel_Pop	Pop_Ages5_9	***Number*** *of people age 5-9*
Parcel_Pop	Pop_Age10_14	***Number*** *of people age 10-14*
Parcel_Pop	Pop_Age15_17	***Number*** *of people age 15-17*
Parcel_Pop	Pop_Age18_19	***Number*** *of people age 18-19*
Parcel_Pop	Pop_Age20	***Number*** *of people age 20*
Parcel_Pop	Pop_Age21	***Number*** *of people age 21*
Parcel_Pop	Pop_Age22_24	***Number*** *of people age 22-24*
Parcel_Pop	Pop_Age25_29	***Number*** *of people age 25-29*
Parcel_Pop	Pop_Age30_39	***Number*** *of people age 30-39*
Parcel_Pop	Pop_Age40_49	***Number*** *of people age 40-49*
Parcel_Pop	Pop_Age50_64	***Number*** *of people age 50-64*
Parcel_Pop	Pop_Age65_Up	***Number*** *of people age 65 and up*
Parcel_Pop	Pop_Age16_Up	***Number*** *of people age 16 and up*
Parcel_Pop	Pop_Age25_Up	***Number*** *of people age 25 and up*
Population by Gender and Age 20 - 64 Years		
Parcel_Pop	Pop_Female_Age20_64	***Number*** *of people who are female and age 20-64*
Parcel_Pop	Pop_Male_Age20_64	***Number*** *of people who are male and age 20-64*
Population by Gender and Age 25 - 64 Years		

Loaded Parcel Fields	***Derivative Loaded Grid Fields***	***Derivative Field Description***
Parcel_Pop	Pop_Female_Age25_64	***Number*** *of people who are female and age 25-64*
Parcel_Pop	Pop_Male_Age25_64	***Number*** *of people who are male and age 25-64*
Population by Educational Attainment		
Parcel_Pop	Pop_in_School	***Number*** *of people in preschool, kindergarten, or grades 1-12*
Parcel_Pop	Pop_in_College	***Number*** *of people in college (undergrad, grad or prof)*
Parcel_Pop	Pop_HS_Not_Comp	***Number*** *of people who did not finish high school*
Parcel_Pop	Pop_HS_Diploma	***Number*** *of people who graduated high school/GED*
Parcel_Pop	Pop_Assoc_Some_Coll	***Number*** *of people with some college education or an associate's degree*
Parcel_Pop	Pop_Coll_Degree	***Number*** *of people who graduated college*
Parcel_Pop	Pop_Grad_Degree	***Number*** *of people with post-college degrees*
Population by Employment Category		
Parcel_Pop	Pop_Employed	***Number*** *of employed residents*
Parcel_Pop	Pop_Employed_Civ	***Number*** *of civilian employed residents*
Parcel_Pop	Pop_Employed_AF	***Number*** *of armed forces employed residents*
Parcel_Pop	Pop_Unemployed	***Number*** *of unemployed residents*
Parcel_Pop	Pop_Not_in_LaborForce	***Number*** *of people not in the labor force*
Parcel_Pop	Pop_Ind_Retail	***Number*** *of people in the retail industry*
Parcel_Pop	Pop_Ind_RestAccom	***Number*** *of employed residents in the restaurant and hotel industry*
Parcel_Pop	Pop_Ind_EntRec	***Number*** *of employed residents in the arts, entertainment, and recreation industries*
Parcel_Pop	Pop_Ind_Office	***Number*** *of people in the office industry (professional, administrative)*
Parcel_Pop	Pop_Ind_Educ	***Number*** *of employed residents in the education industry*
Parcel_Pop	Pop_Ind_MedSS	***Number*** *of employed residents in the health and social services industry*
Parcel_Pop	Pop_Ind_Public	***Number*** *of people in the public administration industry (not including armed forces)*
Parcel_Pop	Pop_Ind_Manuf	***Number*** *of employed residents in the manufacturing industry*
Parcel_Pop	Pop_Ind_TransWare	***Number*** *of employed residents in the transportation and warehousing industry*
Parcel_Pop	Pop_Ind_Util	***Number*** *of employed residents in the utilities industry*
Parcel_Pop	Pop_Ind_Whole	***Number*** *of employed residents in the wholesale industry*
Parcel_Pop	Pop_Ind_Constr	***Number*** *of employed residents in the construction industry*

Loaded Parcel Fields	***Derivative Loaded Grid Fields***	***Derivative Field Description***
Parcel_Pop	Pop_Ind_Other	***Number*** *of employed residents in the repair services (auto, furniture, electronic), laundry, funeral, and not-for-profit (foundations, advocacy, unions, churches) industries*
Parcel_Pop	Pop_Ind_Ag	***Number*** *of employed residents in the farming, forestry, fishing, hunting, and fishing industries*
Parcel_Pop	Pop_Ind_Extract	***Number*** *of employed residents in the oil and mining industry*
Retail Employment Categories by NAICS Code		
Parcel_Emp_Ret	Emp_Retail	***Number*** *of retail jobs*
Parcel_Emp_Ret	Emp_RestAccom	***Number*** *of restaurant, food service, and accommodation jobs*
Parcel_Emp_Ret	Emp_EntRec	***Number*** *of arts, entertainment, and recreation jobs*
Parcel_Emp_Ret	Emp_Other	***Number*** *of repair (auto, electronic, furniture, etc.), laundromat, funeral home, and nonprofit (churches, advocacy groups, unions, foundations, etc.) jobs*
Office Employment Categories by NAICS Code		
Parcel_Emp_Off	Emp_Office	***Number*** *of office jobs*
Parcel_Emp_Off	Emp_Public	***Number*** *of public jobs*
Parcel_Emp_Off	Emp_Educ	***Number*** *of education jobs*
Parcel_Emp_Off	Emp_MedSS	***Number*** *of health care and social service jobs*
Industrial Employment Categories by NAICS Code		
Parcel_Emp_Ind	Emp_TransWare	***Number*** *of transportation and warehousing jobs*
Parcel_Emp_Ind	Emp_Whole	***Number*** *of wholesale jobs*
Parcel_Emp_Ind	Emp_Manuf	***Number*** *of manufacturing jobs*
Parcel_Emp_Ind	Emp_Util	***Number*** *of utility jobs*
Parcel_Emp_Ind	Emp_Constr	***Number*** *of construction jobs*
Agricultural Employment Categories by NAICS Code		
Parcel_Emp_Ag	Emp_Ag	***Number*** *of agriculture, forestry, fishing, and hunting jobs*
Parcel_Emp_Ag	Emp_Extract	***Number*** *of oil and mining jobs*

Step 5: Sum parcel portions attributes to grid scale. In this next step, the model aggregates the loaded parcel portions into the 150-meter grid. This done by summing each field in the parcel portions table grouped on the Grid ID. This results in a table at the grid scale that is partially loaded with most of the main fields in the final loaded base grid.

Step 6: Calculate additional derivative fields. After summing the parcel portion attributes back into the grid, additional derivative fields are calculated. These include a range of percent fields, aggregate fields, and density fields. The percent fields represent the relative percent values for the fields produced in the previous step. Examples of these include the percent of the population that is male and female. Aggregate fields are also calculated in this step, which include specific employment and household income categories. Densities are also calculated at this stage, as the previous step was the final geometric aggregation in the grid load process.

The fields that are created at this step are listed in Table 2-10**.**

Table 2-10: Additional Derivative Fields

Variable Name	*Definition*
Density Variables	
Gross_DU_Dens	*Dwelling units per grid cell acre*
Gross_HH_Dens	*Households per grid cell acre*
Gross_Pop_Dens	*Population per grid cell acre*
Gross_Emp_Dens	*Jobs per grid cell acre*
Gross_Tot_Dens	*Population plus jobs per grid cell acre*
Net_DU_Dens	*Dwelling units per parcel acre*
Net_HH_Dens	*Households per parcel acre*
Net_Pop_Dens	*Population per parcel acre*
Net_Emp_Dens	*Jobs per parcel acre*
Net_Tot_Dens	*Population plus jobs per parcel acre*
Use_DU_Dens	*Dwelling units per residential and mixed use acre*
Use_HH_Dens	*Households per residential and mixed use acre*
Use_Pop_Dens	*Population per residential and mixed use acre*
Use_Emp_Dens	*Jobs per grid employment and mixed use acre*
Household Family Average Fields	
HH_Avg_Children	***Average** number of children (under 18) per household*
Household Tenure Percent and Average Fields	
HH_Own_Occ_Pct	***Percent** of households that are owner occupied*
HH_Rent_Occ_Pct	***Percent** of households that are renter occupied*
Household Income Percent and Average Fields	
HH_Inc_00_10_Pct	***Percent** of households with income under $10,000*
HH_Inc_10_20_Pct	***Percent** of households with income between $10,000-19,999*
HH_Inc_20_30_Pct	***Percent** of households with income between $20,000-29,999*
HH_Inc_30_40_Pct	***Percent** of households with income between $30,000-39,999*
HH_Inc_40_50_Pct	***Percent** of households with income between $40,000-49,999*
HH_Inc_50_60_Pct	***Percent** of households with income between $50,000-59,999*
HH_Inc_60_75_Pct	***Percent** of households with income between $60,000-74,999*
HH_Inc_75_100_Pct	***Percent** of households with income between $75,000-99,999*
HH_Inc_100p_Pct	***Percent** of households with income $100,000 and up*

Variable Name	*Definition*
HH_Inc_100_125_Pct	***Percent*** *of households with income between $100,000-124,999*
HH_Inc_125_150_Pct	***Percent*** *of households with income between $125,000-149,999*
HH_Inc_150_200_Pct	***Percent*** *of households with income between $150,000-199,999*
HH_Inc_200p_Pct	***Percent*** *of households with income $200,000 and up*
HH_Avg_Inc	***Average*** *household income*
Household Vehicle Average Fields	
HH_Avg_Veh	***Average*** *number of vehicles per household*
Population Variables	
Pop_Female_Pct	***Percent*** *of population who is female*
Pop_Male_Pct	***Percent*** *of population who is male*
Pop_White_Not_Hisp_Pct	***Percent*** *of population who is white and not Hispanic/Latino*
Pop_of_Color_Pct	***Percent*** *of population who is a person of color (non-white race nor Hispanic/Latino)*
Pop_Children	***Percent*** *of population under 18 years old*
Pop_Avg_Age	***Average*** *age of the population*
Pop_Avg_Age_of20_64	***Average*** *age of the population that is 20-64*
Pop_Avg_Age_of25_64	***Average*** *age of the population that is 25-64*
Pop_Avg_Age_of20_up	***Average*** *age of the population that is 20 and up*
Pop_Avg_Age_of25_up	***Average*** *age of the population that is 25 and up*
Pop_Female_of_Age20_64_pct	***Percent*** *of population age 20-64 who are female*
Pop_Male_of_Age20_64_pct	***Percent*** *of population age 20-64 who are male*
Pop_HS_Not_Comp_Pct	***Percent*** *of population who did not finish high school*
Pop_HS_Diploma_Pct	***Percent*** *of population who graduated high school/GED*
Pop_Assoc_Some_Coll_Pct	***Percent*** *of population with some college education or an associate's degree*
Pop_Coll_Degree_Pct	***Percent*** *of population who graduated college*
Pop_Grad_Degree_Pct	***Percent*** *of population with post-college degrees*
Job Variables	
Emp_VMT_Office	*The sum of Emp_Office, Emp_MedSS, and Emp_AF (for purposes of the VMT engine)*
Emp_VMT_Public	*The sum of Emp_Public and Emp_Educ (for purposes of the VMT engine)*
Emp_Industry	*The sum of Emp_Manuf, Emp_TransWare, Emp_Util, Emp_Whole, Emp_Constr, Emp_Other, Emp_Ag, and Emp_Extract (for purposes of the VMT engine)*
Emp_Industry_No_Ag	*The same as Emp_Industry, except Emp_Ag and Emp_Extract are excluded.*

Step 6: Calculate building square footage using square feet per employee assumptions. The final step in the grid load process is to calculate building square feet for residential and commercial buildings. The model assumes that for both residential and commercial buildings, building size will vary depending on whether a building is located in a suburban or an urban environment. The designation of whether a grid cell is urban or suburban is based on the intersection density per square mile around each grid cell. If a grid cell has an intersection density per square mile greater than 150 meters it is considered urban while below that threshold, the grid cell is considered suburban/rural. For residential building square feet, the model applies an average square footage per dwelling unit by type, adjusted for urban and suburban locations. For commercial buildings, the model calculates building square footage based on square

footage per employee rates by NAICS category, which is adjusted for urban and suburban environments. In this way, building square footage will vary with employment totals at the grid cell scale. The building square feet factors for residential and commercial buildings are listed in Table 2-11**.**

Table 2-11: Residential Building Square Feet Factors

Loaded Grid Field	Field Description	Suburban Sq. ft./Unit	Urban Sq. ft./Unit
bldg_sqft_detsf_sl	*Small Lot Single Family Dwelling Units*	2400	1650
bldg_sqft_detsf_ll	*Large Lot Single Family Dwelling Units*	3000	2100
bldg_sqft_attsf	*Attached Single Family Dwelling Units*	1800	1800
bldg_sqft_mf2to4	*Multifamily 2 to 4 units*	2000	1850
bldg_sqft_mf5p	*Multifamily 5 plus units units*	1200	1200

Table 2-12: Employment Building Square Feet Factors

Loaded Grid Field	*Field Description*	*Suburban Sq. ft./Employee*	*Urban Sq. ft./Employee*
Retail building sq. ft.			
Bldg_sqft_retail	*retail services*	750	475
Bldg_sqft_restaccom	*restaurant and accommodation*	750	475
Bldg_sqft_entrec	*entertainment and recreation*	800	575
Bldg_sqft_other	*other services*	600	525
Office building sq. ft.			
Bldg_sqft_Office	*office services*	350	275
Bldg_sqft_educ	*education services*	3000	2625
Bldg_sqft_medss	*medical and health services*	800	725
Bldg_sqft_public	*public administration*	400	325
Industrial building sq. ft.			
Bldg_sqft_manuf	*manufacturing*	650	575
Bldg_sqft_transware	*transportation and warehousing*	700	625
Bldg_sqft_util	*utilities*	350	275
Bldg_sqft_whole	*wholesale*	700	625
Bldg_sqft_constr	*construction*	400	275
Military building sq. ft.			
Bldg_sqft_af	*armed forces*	600	525

Step 7: Load walkable intersection data into the base grid. This final step of the base grid load process adds the intersection fields from the walkable intersection table, joining them on the grid ID.

Loaded Base Grid

The final loaded grid represents the synthesis of modeled parcel scale data, informed by various census scales and provides a robust canvas for the creation of future land use scenarios. In addition, it provides a key data set for calibrating UrbanFootprint modules, including the VMT, energy and water and public health modules.

CHAPTER 3

Scenario Building Blocks: Place Types and Building Types

UrbanFootprint version 1.0 includes a library of more than 35 place types (see Figure 3-1) and over 50 building types (see Figure 3-2) that make up the palette of development options used to translate or "paint" scenarios. Place types – each composed of a mix of building types (based on studies of over 300 real-world buildings) – are the land use building blocks of future scenarios at version 1.0, and represent the complete range of potential development types and patterns that make up a scenario. They include a range of mixed-use centers, residential areas of varying densities and types, employment and industrial areas, and other land use types that make up existing and future urban land uses. Future versions of UrbanFootprint, currently under development with major Metropolitan Planning Organizations in California, will also allow users to paint building types on parcels, representing a more specific set of descriptions of land use at the local rather than neighborhood level. Building types include buildings of various heights and uses, from main-street mixed-use buildings, to single family homes, from skyscrapers to warehouses, strip malls to schools, and other general types of buildings likely to be built in a future scenario.

Figure 3-1: UrbanFootprint v1.0 California Place Types

	Mixed Use Centers and Corridors
1	Urban Mixed Use
2	Urban Residential
3	Urban Commercial
4	City Mixed Use
5	City Residential
6	City Commercial
7	Town Mixed Use
8	Town Residential
9	Town Commercial
10	Village Mixed Use
11	Village Residential
12	Village Commercial
13	Neighborhood Residential
14	Neighborhood Low
	Employment Areas
15	Office Focus
16	Mixed Office and R&D
17	Office/Industrial
18	Industrial Focus
19	Low-Density Employment Park
	Suburban Commercial/Mixed Use
20	High Intensity Activity Center
21	Mid Intensity Activity Center
22	Low Intensity Retail-Centered Neighborhood
23	Retail: Strip Mall/ Big Box
24	Industrial/Office/Res Mixed High
25	Industrial/Office/Res Mixed Low
	Suburban Residential Single Use
26	Suburban Multifamily
27	Suburban Mixed Residential
28	Residential Subdivision
29	Large Lot Residential Area
	Rural
30	Rural Residential
31	Rural Ranchettes
32	Rural Employment
	Institutional
33	Campus/ University
34	Institutional

Place and building types are calibrated based on studies of real places across California and the US, as well as detailed studies of a complete range of building types across California and the West. Calthorpe Associates' UrbanFootprint Place and Building Type library can be utilized by cities, regions, or other entities as they develop their own plans – either as an "off the shelf" library or customized for their specific needs. Future versions of UrbanFootprint will allow users to edit and add to these types, facilitating easy customization of the tool for their area.

Place types, and the buildings within them, are "loaded" with a unique set of assumptions that facilitate scenario modeling and testing at a variety of scales. Some assumptions are related to the individual building types in a Place Type (i.e. commercial mid-rise, single family home, townhome), including:

- o Building energy and water consumption
- o Building-related greenhouse gas emissions
- o Infrastructure cost/burden (including operations and maintenance costs)
- o Household utility costs and tax burden

Other assumptions are related to each Place Type's unique density, location, transportation network, demographic context, and combination of buildings. Variables that reflect this for each Place Type include: site size; block size; densities; Floor Area Ratio; land uses; population; housing; employment; and streets.

These assumptions combine to predict the travel behavior of a scenario's residents and employees and are thus critical in measuring passenger vehicle miles traveled (VMT), roadway congestion, transportation-related greenhouse gas emissions, air pollutant emissions, public health outcomes, and state, regional, local, and household transportation cost burdens.

Figure 3-2: UrbanFootprint v1.0 Building Types

	Mixed Use Buildings		**Commercial/Industrial Buildings**
1	Skyscraper Mixed Use	31	Office Park High
2	High-Rise Mixed Use	32	Office Park Low
3	Mid-Rise Mixed Use	33	Industrial High
4	Low-Rise Mixed Use	34	Industrial Low
5	Parking Structure/Mixed Use	35	Warehouse High
6	Main Street Commercial/Mixed Use High (3-5 Floors)	36	Warehouse Low
7	Main Street Commercial/Mixed Use Low (1-2 Floors)	37	Hotel High
	Mixed Use Buildings	38	
8	Skyscraper Residential	39	Regional Mall
9	High-Rise Residential	40	Medium Intensity Strip Commercial
10	Urban Mid-Rise Residential	41	Low Intensity Strip Commercial
11	Urban Podium Multi-Family	42	Rural Employment

12	Standard Podium Multi-Family
13	Suburban Multifamily Apt/Condo
14	Urban Townhome/Live-Work
15	Standard Townhome
16	Garden Apartment
17	Very Small Lot 3000
18	Small Lot 4000
19	Medium Lot 5500
20	Large Lot 7500
21	Estate Lot
22	Rural Residential
23	Rural Ranchette
Commercial/Industrial Buildings	
24	Skyscraper Office
25	High-Rise Office
26	Mid-Rise Office
27	Low-Rise Office
28	Main Street Commercial (Retail + Office/Medical)
29	Parking Structure + Ground Floor Retail
30	Parking Structure

	Institutional Buildings
43	Campus/College High
44	Campus/College Low
45	Hospital/Civic/Other Institutional
	Civic Buildings
46	Urban Elementary School
47	Non-Urban Elementary School
48	Urban Middle School
49	Non-Urban Middle School
50	Urban City Hall
51	Urban Public Library
52	Urban Courthouse
53	Urban Convention Center
54	Suburban Civic Complex
55	Town Civic Complex
56	Town/Branch Library
57	Church
	Other Buildings
58	Military/General Catch-All
59	Low Density Commercial

The Compass Rose Place Types

The Compass Rose place types are an expanded library of place types utilized for more detailed translation of input scenarios and scenario editing. In order to provide a higher level of detail during the place type translation process, Calthorpe Associates has added the option to provide another level of complexity to the base set of 35 place types. The Compass Rose set of place types consists of five separate versions of each named place type, with the name of each version corresponding to the four corners of the compass rose (NW, NE, SE, SW) as well as the center (C).

Compass Rose place types are derived by splitting the density ranges of standard UrbanFootprint place types into the five named directions using density ranges. This increases the detail in classifying input scenario categories to their associated place types and provides more accuracy in matching derived place type attributes to the input data.

The full Compass Rose Translation ranges can be viewed in Figure 3-3, the Place Type Translation Graph. On this graph the X-axis represents gross residential density (expressed as residential dwelling units per acre), and the Y-axis represents gross employment density (expressed as employees [workers at work] per acre). When the compass rose is laid over this graph, the NE directional “flavor” of each place type is the one that expresses the highest level of residential and employment density; SE has higher residential density and lower employment density; SW has the lowest residential and employment density; NW has higher employment density but lower residential density; and C represents a median setting.

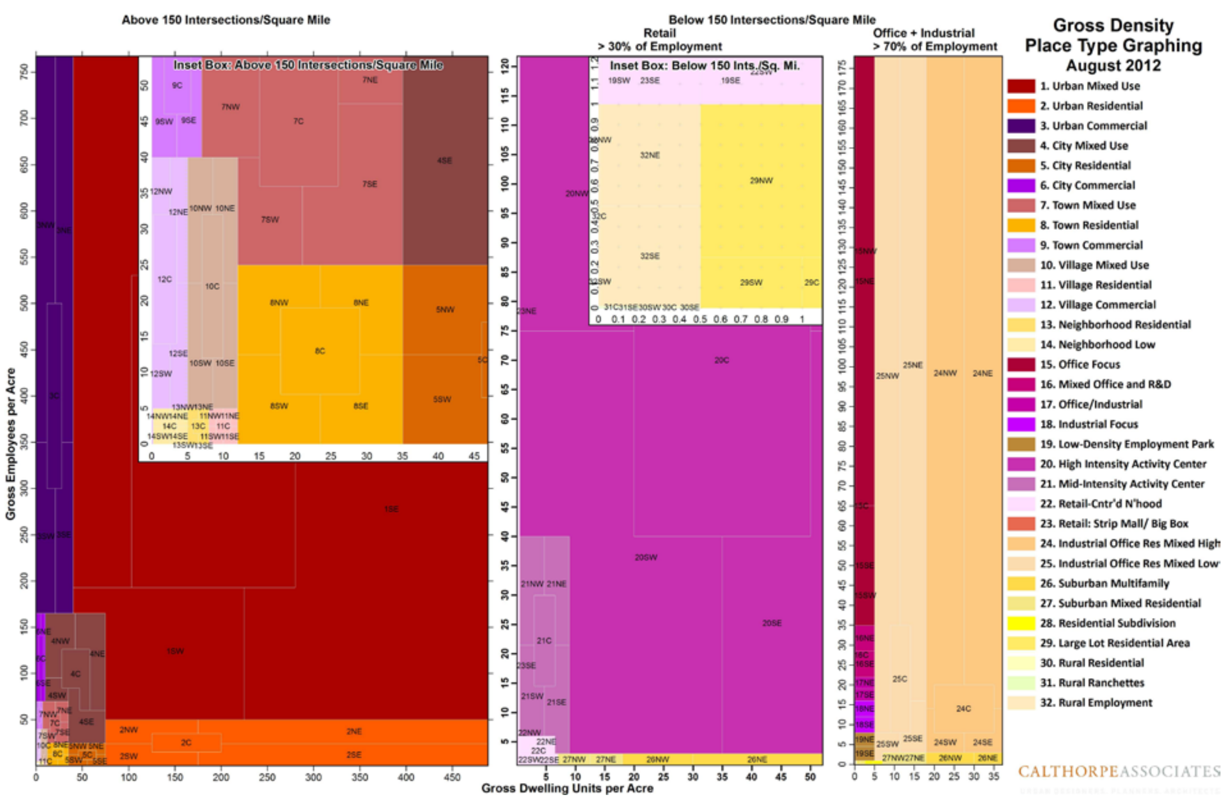


Figure 3-3: Compass Rose Place Type Translation Graph showing density ranges

Application of Place Types

When place types are applied via painting or translation to describe the urban form of new development (whether it be in greenfield locations or in the form of refill[3]), UrbanFootprint uses their attributes to describe new buildings, which are then blended with the attributes of the existing buildings (as defined during the existing year base loading process).

Detailed place type sheets are located in the Appendix.

Built Form Variables and Equations

What follows is a list of the variables used by UrbanFootprint's Built Form engine. Each of these fields is found in .csv files imported into UrbanFootprint version 1.0, and within the UrbanFootprint PostgreSql/Django database in subsequent versions of the model (currently under development). Information about individual buildings is blended into building types, which are themselves blended with information about streets, parks, utilities and civic buildings to create place types.

record_id

This is the auto-generated unique identifier for each record, allowing for joins to other tables.

classtype [input]

For buildings and building types, refers to the overall class of buildings, i.e. Mixed Use, Residential, Employment, Civic, or Agricultural.

name [input]

Name of the building, building type or place type (text).

pt_num [input]

Place type number (text), sometimes used as a unique ID when referring to place types.

direction [input]

Place type compass rose direction (NW, NE, SE, SW or C), used when referring to Compass Rose place types.

ptid

Unique identifier, combination of pt_num + direction.

Place_type [input]

Name of the place type.

intersections_sqmi [input]

Walkable street intersections per square mile for the place type. This is an input at version 1.0, but the logic has been developed to allow it to be calculated in future versions of UrbanFootprint based on local street network characteristics such as block length, block width, street right-of-way width and other

[3] Refill is a term that includes all forms of development on already-urbanized land, including infill, redevelopment and development on brownfield sites.

factors for future place types. For the existing environment, this is measured based on the existing street network. Measurements of existing street intersections per square mile for place type study areas are used to calibrate this input for future place types.

gross_net_ratio

Gross to net ratio for the place type represents the amount of gross land that is developable on the net. A gross-to-net ratio of 0.55, for instance, means that 55% of the gross land is available for development, generally in the form of developable parcel area.

Equation 3-1: gross_net_ratio calculation

$$GN_r = 1 - (CS_{perc} + CP_{perc} + CU_{perc} + CC_{perc})$$

where:

GN_r = **gross_net_ratio:** The ratio between total land and land developable for new non-civic buildings

CS_{perc} = **streets_percent:** The percent of a hypothetical place type acre devoted to the street right-of-way

CP_{perc} = **parks_percent:** The percent of a hypothetical place type acre devoted to parks

CU_{perc} = **utilities_percent:** The percent of a hypothetical place type acre devoted to utilities and runoff water retention/detention facilities

CC_{perc} = **civic_percent:** The percent of a hypothetical place type acre devoted to civic and institutional buildings and uses

pop_density

Population density is calculated as a product of household size and household density.

Equation 3-2: pop_density calculation

$$P_d = HH_{sz} * HH_d$$

where:

P_d = **pop_density:** Population density

HH_{sz} = **hh_average_size:** Household size (average)

HH_d = **hh_density:** Household density

du_density

Density of dwelling units is derived differently depending on the residential building type. For multifamily and townhome buildings, it is calculated based on total residential built up area and the average square feet per dwelling unit. For single family homes, it is based on the size of the lot.

Equation 3-3: du_density calculation for multifamily units and townhomes

$$DU_d = RBUA_n / DU_{sfa}$$

where:

DU_d = **DU_density:** Density of dwelling units

DU_{sfa} = **square_feet_per_du_average:** Square feet per dwelling unit (average) [input]

$RBUA_n$ = **residential_building_square_feet_net:** Residential building (built up area) in square feet (net, excluding residential common areas)

Equation 3-4: du_density calculation for single family homes

$$DU_d = C_{sfac}/L_{sz}$$

where:

DU_d = **DU_density:** Density of dwelling units

L_{sz} = **lot_size_average:** Residential parcel lot size (average) [input]

C_{sfac} = **square_feet_per_acre:** Square feet per acre (conversion factor; 43,560:1)

du_use_density

Density of dwelling units on residential parcel acres is derived as total dwelling units over parcel acres containing a residential use.

Equation 3-5: du_use_density calculation

$$DU_{ud} = DU_d/RU_{ac}$$

where:

DU_{ud} = **DU_use_density:** Use density of dwelling units

DU_d = **DU_density:** Density of dwelling units

RU_{ac} = **residential_use_acres:** Parcel acres containing a residential use

building_percent_residential [input]

Percent of each building that is residential. This is an input that is used to define the characteristics of each building.

building_percent_retail [input]

Percent of each building that is retail employment. This is an input that is used to define the characteristics of each building.

building_percent_office [input]

Percent of each building that is office employment. This is an input that is used to define the characteristics of each building.

building_percent_industrial [input]

Percent of each building that is industrial employment. This is an input that is used to define the characteristics of each building.

building_percent_agriculture [input]

Percent of each building that is agricultural employment. This is an input that is used to define the characteristics of each building.

building_percent_armed_forces [input]

Percent of each building that is armed forces employment. This is an input that is used to define the characteristics of each building.

floor_area_ratio [input]

The Floor Area Ratio (FAR) is an input used to define the characteristics of each building. When calculating its characteristics for place types, however, it should be derived as total building square feet of gross building built up area (gross BUA) over total parcel square feet (rather than as a weighted average of component building FAR values). This gives what is known as the net FAR. (Gross FAR uses total site area as the denominator, with the definition of "site" causing a good degree of variability in its values and meaning.)

Equation 3-6: floor_area_ratio calculation for place types

$$FAR_n = BUA_g / PA_{sf}$$

where:

FAR_n	=	**floor_area_ratio:** The ratio between floor area and land area
BUA_g	=	**building_square_feet_total_gross:** Total gross built up area in buildings (conditioned space)
PA_{sf}	=	**parcel_square_feet:** Total parcel square feet

floor_area_ratio_residential

The residential Floor Area Ratio (FAR) is derived differently depending on the building type. For multifamily and townhome, the calculation is based on total FAR and the residential building percent. For single family homes, the calculation involves the average single family lot size and the average square feet per dwelling unit.

Equation 3-7: floor_area_ratio_residential calculation for multifamily and townhome building types

$$FAR_{nres} = BR_{perc} * FAR_n$$

where:

FAR_{nres}	=	**floor_area_ratio_residential:** The ratio between residential floor area and land area
FAR_n	=	**floor_area_ratio:** The ratio between floor area and land area [input]
BR_{perc}	=	**building_percent_residential:** Building percent that is residential [input]

Equation 3-8: floor_area_ratio_residential calculation for single family building types

$$FAR_{nres} = DU_{sqft} / L_{sz}$$

where:

FAR_{nres}	=	**floor_area_ratio_residential:** The ratio between residential floor area and land area
L_{sz}	=	**lot_size_average:** Residential parcel lot size (average) [input]
DU_{sqft}	=	**square_feet_per_du_average:** Square feet per dwelling unit (average) [input]

floor_area_ratio_retail

The retail Floor Area Ratio (FAR) calculation is based on total FAR and the retail building percent.

Equation 3-9: floor_area_ratio_retail calculation

$$FAR_{nret} = BER_{perc} * FAR_n$$

where:

FAR_{nret} = **floor_area_ratio_retail:** The ratio between retail floor area and land area

FAR_n = **floor_area_ratio:** The ratio between floor area and land area [input]

BER_{perc} = **building_percent_retail:** Building percent that is retail employment [input]

floor_area_ratio_office

The office Floor Area Ratio (FAR) calculation is based on total FAR and the office building percent.

Equation 3-10: floor_area_ratio_office calculation

$$FAR_{noff} = BEO_{perc} * FAR_n$$

where:

FAR_{noff} = **floor_area_ratio_office:** The ratio between office floor area and land area

FAR_n = **floor_area_ratio:** The ratio between floor area and land area [input]

BEO_{perc} = **building_percent_office:** Building percent that is office employment [input]

floor_area_ratio_industrial

The industrial Floor Area Ratio (FAR) calculation is based on total FAR and the industrial building percent.

Equation 3-11: floor_area_ratio_industrial calculation

$$FAR_{nind} = BEI_{perc} * FAR_n$$

where:

FAR_{nind} = **floor_area_ratio_industrial:** The ratio between industrial floor area and land area

FAR_n = **floor_area_ratio:** The ratio between floor area and land area [input]

BEI_{perc} = **building_percent_industrial:** Building percent that is industrial employment [input]

floor_area_ratio_agriculture

The agriculture Floor Area Ratio (FAR) calculation is based on total FAR and the agriculture building percent.

Equation 3-12: floor_area_ratio_agriculture calculation

$$FAR_{nag} = BEA_{perc} * FAR_n$$

where:

FAR_{nag} = **floor_area_ratio_agriculture:** The ratio between agricultural floor area and land area

FAR_n = **floor_area_ratio:** The ratio between floor area and land area [input]

BEA_{perc} = **building_percent_agriculture:** Building percent that is agricultural employment [input]

floor_area_ratio_armed_forces

The armed forces Floor Area Ratio (FAR) calculation is based on total FAR and the armed forces building percent.

Equation 3-13: floor_area_ratio_armed_forces calculation

$$FAR_{naf} = BEAF_{perc} * FAR_n$$

where:

FAR_{naf} = **floor_area_ratio_armed_forces:** The ratio between armed forces floor area and land area

FAR_n = **floor_area_ratio:** The ratio between floor area and land area [input]

$BEAF_{perc}$ = **building_percent_armed_forces:** Building percent that is armed forces employment [input]

residential_use_acres

Residential use acres are defined as parcel acres containing a residential use.

detached_single_family_large_lot_density

Density of single family large lot dwelling units is derived as total single family large lot dwelling units over total parcel acres.

Equation 3-14: detached_single_family_large_lot_density calculation

$$SFLL_d = SFLL_{du}/PA_{ac}$$

where:

$SFLL_d$ = **detached_single_family_large_lot_density:** Density of detached single family large lot dwelling units on total parcel acres

$SFLL_{du}$ = **detached_single_family_large_lot_units:** Total detached single family large lot dwelling units

PA_{ac} = **parcel_acres:** Total parcel acres

detached_single_family_small_lot_density

Density of single family small lot dwelling units is derived as total single family small lot dwelling units over total parcel acres.

Equation 3-15: detached_single_family_small_lot_density calculation

$$SFSL_d = SFSL_{du}/PA_{ac}$$

where:

$SFSL_d$ = **detached_single_family_small_lot_density:** Density of detached single family small lot dwelling units on total parcel acres

$SFSL_{du}$ = **detached_single_family_small_lot_units:** Total detached single family small lot dwelling units

PA_{ac} = **parcel_acres:** Total parcel acres

attached_single_family_density

Density of single family attached (town home) dwelling units is derived as total single family attached dwelling units over total parcel acres.

Equation 3-16: attached_single_family_density calculation

$$SFLL_d = SFLL_{du}/PA_{ac}$$

where:

TH_d = **attached_single_family_density:** Density of attached single family dwelling units on total parcel acres

TH_{du} = **attached_single_family_units:** Total attached single family dwelling units

PA_{ac} = **parcel_acres:** Total parcel acres

multifamily_density

Density of multifamily dwelling units is derived as total multifamily dwelling units over total parcel acres.

Equation 3-17: multifamily_density calculation

$$MF_d = MF_{du}/PA_{ac}$$

where:

MF_d = **multifamily_density:** Density of multifamily dwelling units on total parcel acres

MF_{du} = **multifamily_units:** Total multifamily dwelling units

PA_{ac} = **parcel_acres:** Total parcel acres

hh_density

Density of households is derived from total dwelling units based on the vacancy rate.

Equation 3-18: hh_density calculation

$$HH_d = DU_d * (1 - V_r)$$

where:

HH_d = **hh_density:** Total households per acre

DU_d = **DU_density:** Density of dwelling units

V_r = **residential_vacancy_rate:** Unoccupied percentage of total dwelling units (inverse of occupancy rate).

hh1_percent [input]

Percent of all households with one person. This is an input that is used to define the distribution of households by size.

hh2_percent [input]

Percent of all households with two people. This is an input that is used to define the distribution of households by size.

hh3_percent [input]

Percent of all households with three people. This is an input that is used to define the distribution of households by size.

hh4_percent [input]

Percent of all households with four people. This is an input that is used to define the distribution of households by size.

hh5p_percent [input]

Percent of all households with five or more people. This is an input that is used to define the distribution of households by size.

hh1

Number of households with one person. This is derived from the percent of all households with one person and the total number of households.

Equation 3-19: hh1 calculation

$$HH_1 = HH_{1perc} * HH_d$$

where:

HH_1 = **hh1:** Number of households with one person

HH_{1perc} = **hh1_percent:** Percent of all households that contain one person. [Input]

HH_d = **hh_density:** Household density

hh2

Number of households with two people. This is derived from the percent of all households with two people and the total number of households.

Equation 3-20: hh2 calculation

$$HH_2 = HH_{2perc} * HH_d$$

where:

HH_2 = **hh2:** Number of households with two people

HH_{2perc} = **hh2_percent:** Percent of all households that contain two people. [Input]

HH_d = **hh_density:** Household density

hh3

Number of households with three people. This is derived from the percent of all households with three people and the total number of households.

Equation 3-21: hh3 calculation

$$HH_3 = HH_{3perc} * HH_d$$

where:

HH_3 = **hh3:** Number of households with three people

HH_{3perc} = **hh3_percent:** Percent of all households that contain three people. [Input]

HH_d = **hh_density:** Household density

hh4

Number of households with four people. This is derived from the percent of all households with four people and the total number of households.

Equation 3-22: hh4 calculation

$$HH_4 = HH_{4perc} * HH_d$$

where:

HH_4 = **hh4:** Number of households with four people

HH_{4perc} = **hh4_percent:** Percent of all households that contain four people. [Input]

HH_d = **hh_density:** Household density

hh5p

Number of households with five or more people. This is derived from the percent of all households with five or more people and the total number of households.

Equation 3-23: hh5p calculation

$$HH_{5p} = HH_{5pperc} * HH_d$$

where:

HH_{5p} = **hh5p:** Number of households with five or more people

HH_{5pperc} = **hh5p_percent:** Percent of all households that contain five or more people. [Input]

HH_d = **hh_density:** Household density

hh_average_size

Average household size. This is derived from the number of households by household size category and the total number of households.

Equation 3-24: hh_average_size calculation

$$HH_{sz} = ((HH_1 * 1) + (HH_2 * 2) + (HH_3 * 3) + (HH_4 * 4) + (HH_{5p} * 5.5))/HH_d$$

where:

HH_{sz} = **hh_average_size:** Household size (average)

HH_1 = **hh1:** Number of households with one person

HH_2 = **hh2:** Number of households with two people

HH_3 = **hh3:** Number of households with three people

HH_4 = **hh4:** Number of households with four people

HH_{5p} = **hh5p:** Number of households with five or more people

HH_d = **hh_density:** Household density

residential_vacancy_rate [input]

Unoccupied percentage of total dwelling units (inverse of occupancy rate); building-level input.

square_feet_per_du_average [input]

Average square feet per residential dwelling unit. This is an input that is used to calculate residential density, among other things.

residential_building_square_feet_gross

Total square feet of building associated with residential uses, including common areas. This is derived from the residential Floor Area Ratio (FAR).

Equation 3-25: residential_building_square_feet_gross calculation

$$RBUA_g = FAR_{res} * C_{sfac}$$

where:

$RBUA_g$ = **residential_building_square_feet_gross:** Total residential building square feet (built up area), including common areas

FAR_{nres} = **floor_area_ratio_residential:** Residential FAR (net)

C_{sfac} = **square_feet_per_acre:** Square feet per acre (conversion factor; 43,560:1)

residential_percent_efficiency [input]

The percent of residential_building_square_feet_gross that is leasable to tenants; the inverse of which represents residential common areas.

residential_building_square_feet_net

The leasable portion of a residential building; that is, the amount contained within dwelling units, excluding indoor residential common areas.

Equation 3-26: residential_building_square_feet_net calculation

$$RBUA_n = RBUA_g * RE_{perc}$$

where:

$RBUA_n$ = **residential_building_square_feet_net:** The amount of a residential building contained within dwelling units, excluding indoor residential common areas

$RBUA_g$ = **residential_building_square_feet_gross:** Total residential building square feet (built up area), including common areas

RE_{perc} = **residential_percent_efficiency:** The percent of residential_building_square_feet_gross that is leasable to tenants

emp_density

The density of total employees (workers at work) per acre. This is calculated by summing the densities of each of the employment types.

Equation 3-27: emp_density calculation

$$EMP_d = EMPR_d + EMPO_d + EMPI_d + EMPAG_d + EMPAF_d$$

where:

EMP_d = **emp_density:** The density of total employees (workers at work) per acre.

$EMPR_d$ = **emp_retail_density:** The density of retail employees (workers at work) per acre.

$EMPO_d$ = **emp_office_density:** The density of office employees (workers at work) per acre.

$EMPI_d$ = **emp_industrial_density:** The density of industrial employees (workers at work) per acre.

$EMPAG_d$ = **emp_agriculture_density:** The density of agricultural employees (workers at work) per acre.

$EMPAF_d$ = **emp_armed_forces_density:** The density of armed forces employees (workers at work) per acre.

emp_use_density

Density of employees (workers at work) on employment parcel acres is derived as total employees over parcel acres containing an employment use.

Equation 3-28: emp_use_density calculation

$$EMP_{ud} = EMP_d / EU_{ac}$$

where:

EMP_{ud} = **EMP_use_density:** Use density of employment

EMP_d = **EMP_density:** Density of employees

EU_{ac} = **employment_use_acres:** Parcel acres containing an employment use

employment_use_acres

Employment use acres are defined as parcel acres containing an employment use.

emp_retail_density

The density of total retail employees (workers at work) per acre. This is calculated based on the net retail building square feet and the square feet per retail employee.

Equation 3-29: emp_retail_density calculation

$$EMPR_d = ERBUA_n / EMPR_{sfa}$$

where:

$EMPR_d$ = **emp_retail_density:** The density of retail employees (workers at work) per acre

$EMPR_{sfa}$ = **square_feet_per_retail_employee_average:** The square feet per retail employee [input]

$ERBUA_n$ = **building_square_feet_retail_net:** The total amount of leasable retail building square feet

emp_office_density

The density of total office employees (workers at work) per acre. This is calculated based on the net office building square feet and the square feet per office employee.

Equation 3-30: emp_office_density calculation

$$EMPO_d = EOBUA_n/EMPO_{sfa}$$

where:

$EMPO_d$ = **emp_office_density:** The density of office employees (workers at work) per acre

$EMPO_{sfa}$ = **square_feet_per_office_employee_average:** The square feet per office employee [input]

$EOBUA_n$ = **building_square_feet_office_net:** The total amount of leasable office building square feet

emp_industrial_density

The density of total industrial employees (workers at work) per acre. This is calculated based on the net industrial building square feet and the square feet per industrial employee.

Equation 3-31: emp_industrial_density calculation

$$EMPI_d = EIBUA_n/EMPI_{sfa}$$

where:

$EMPI_d$ = **emp_industrial_density:** The density of industrial employees (workers at work) per acre

$EMPI_{sfa}$ = **square_feet_per_industrial_employee_average:** The square feet per industrial employee [input]

$EIBUA_n$ = **building_square_feet_industrial_net:** The total amount of leasable industrial building square feet

emp_agriculture_density

The density of total agricultural employees (workers at work) per acre. This is calculated based on the net agricultural building square feet and the square feet per agricultural employee.

Equation 3-32: emp_agriculture_density calculation

$$EMPAG_d = EAGBUA_n/EMPAG_{sfa}$$

where:

$EMPAG_d$ = **emp_agriculture_density:** The density of agricultural employees per acre

$EMPAG_{sfa}$ = **square_feet_per_agricultural_employee_average:** The square feet per agricultural employee [input]

$EAGBUA_n$ = **building_square_feet_agriculture_net:** The total amount of leasable agricultural building square feet

emp_armed_forces_density

The density of total armed forces employees (workers at work) per acre. This is calculated based on the net armed forces building square feet and the square feet per armed forces employee.

Equation 3-33: emp_armed_forces_density calculation

$$EMPAF_d = EAFBUA_n/EMPAF_{sfa}$$

where:

$EMPAF_d$ = **emp_armed_forces_density:** The density of armed forces employees (workers at work) per acre

$EMPAF_{sfa}$ = **square_feet_per_armed_forces_employee_average:** The square feet per armed forces employee [input]

$EAFBUA_n$ = **building_square_feet_armed_forces_net:** The total amount of leasable armed forces building square feet

square_feet_per_retail_employee_average [input]

The amount of net building square feet per retail employee; this is a building-level input.

square_feet_per_office_employee_average [input]

The amount of net building square feet per office employee; this is a building-level input.

square_feet_per_industrial_employee_average [input]

The amount of net building square feet per industrial employee; this is a building-level input.

square_feet_per_agricultural_employee_average [input]

The amount of net building square feet per agricultural employee; this is a building-level input.

square_feet_per_armed_forces_employee_average [input]

The amount of net building square feet per armed forces employee; this is a building-level input.

retail_percent_efficiency [input]

The percent of building_square_feet_retail_gross that is leasable to tenants; the inverse of which represents building common areas. This is a building-level input.

office_percent_efficiency [input]

The percent of building_square_feet_office_gross that is leasable to tenants; the inverse of which represents building common areas. This is a building-level input.

industrial_percent_efficiency [input]

The percent of building_square_feet_industrial_gross that is leasable to tenants; the inverse of which represents building common areas. This is a building-level input.

agriculture_percent_efficiency [input]

The percent of building_square_feet_agriculture_gross that is leasable to tenants; the inverse of which represents building common areas. This is a building-level input.

armed_forces_percent_efficiency [input]

The percent of building_square_feet_armed_forces_gross that is leasable to tenants; the inverse of which represents building common areas. This is a building-level input.

building_square_feet_retail_gross

Total square feet of building associated with retail uses, including common areas. This is derived from the retail Floor Area Ratio (FAR).

Equation 3-34: building_square_feet_retail_gross calculation

$$ERBUA_g = FAR_{nret} * C_{sfac}$$

where:

$ERBUA_g$ = **building_square_feet_retail_gross:** Total retail building square feet (built up area), including common areas

FAR_{nret} = **floor_area_ratio_retail:** The ratio between retail floor area and land area

C_{sfac} = **square_feet_per_acre:** Square feet per acre (conversion factor; 43,560:1)

building_square_feet_office_gross

Total square feet of building associated with office uses, including common areas. This is derived from the office Floor Area Ratio (FAR).

Equation 3-35: building_square_feet_office_gross calculation

$$EOBUA_g = FAR_{noff} * C_{sfac}$$

where:

$EOBUA_g$ = **building_square_feet_office_gross:** Total office building square feet (built up area), including common areas

FAR_{noff} = **floor_area_ratio_office:** The ratio between office floor area and land area

C_{sfac} = **square_feet_per_acre:** Square feet per acre (conversion factor; 43,560:1)

building_square_feet_industrial_gross

Total square feet of building associated with industrial uses, including common areas. This is derived from the industrial Floor Area Ratio (FAR).

Equation 3-36: building_square_feet_industrial_gross calculation

$$EIBUA_g = FAR_{nind} * C_{sfac}$$

where:

$EIBUA_g$ = **building_square_feet_industrial_gross:** Total industrial building square feet (built up area), including common areas

FAR_{nind} = **floor_area_ratio_industrial:** The ratio between industrial floor area and land area

C_{sfac} = **square_feet_per_acre:** Square feet per acre (conversion factor; 43,560:1)

building_square_feet_agriculture_gross

Total square feet of building associated with agricultural uses, including common areas. This is derived from the agricultural Floor Area Ratio (FAR).

Equation 3-37: building_square_feet_agriculture_gross calculation

$$EAGBUA_g = FAR_{nag} * C_{sfac}$$

where:

$EAGBUA_g$ = **building_square_feet_agriculture_gross:** Total agricultural building square feet (built up area), including common areas

FAR_{nag} = **floor_area_ratio_agriculture:** The ratio between agricultural floor area and land area

C_{sfac} = **square_feet_per_acre:** Square feet per acre (conversion factor; 43,560:1)

building_square_feet_armed_forces_gross

Total square feet of building associated with armed forces uses, including common areas. This is derived from the armed forces Floor Area Ratio (FAR).

Equation 3-38: building_square_feet_armed_forces_gross calculation

$$EAFBUA_g = FAR_{naf} * C_{sfac}$$

where:

$EAFBUA_g$ = **building_square_feet_armed_forces_gross:** Total armed forces building square feet (built up area), including common areas

FAR_{naf} = **floor_area_ratio_armed_forces:** The ratio between armed forces floor area and land area

C_{sfac} = **square_feet_per_acre:** Square feet per acre (conversion factor; 43,560:1)

building_square_feet_retail_net

The leasable retail portion of building; that is, the amount contained within retail stores, excluding indoor building common areas.

Equation 3-39: building_square_feet_retail_net calculation

$$ERBUA_n = ERBUA_g * ERE_{perc}$$

where:

$ERBUA_n$ = **building_square_feet_retail_net:** The amount of a building contained within retail stores, excluding indoor building common areas

$ERBUA_g$ = **building_square_feet_retail_gross:** Total retail building square feet (built up area), including common areas

ERE_{perc} = **retail_percent_efficiency:** The percent of building_square_feet_retail_gross that is leasable to tenants

building_square_feet_office_net

The leasable office portion of building, excluding indoor building common areas.

Equation 3-40: building_square_feet_office_net calculation

$$EOBUA_n = EOBUA_g * EOE_{perc}$$

where:

$EOBUA_n$ = **building_square_feet_office_net:** The amount of a building in office usage, excluding indoor building common areas

$EOBUA_g$ = **building_square_feet_office_gross:** Total office building square feet (built up area), including common areas

EOE_{perc} = **office_percent_efficiency:** The percent of building_square_feet_office_gross that is leasable to tenants

building_square_feet_industrial_net

The leasable industrial portion of building, excluding indoor building common areas.

Equation 3-41: building_square_feet_industrial_net calculation

$$EIBUA_n = EIBUA_g * EIE_{perc}$$

where:

$EIBUA_n$ = **building_square_feet_industrial_net:** The amount of a building in industrial usage, excluding indoor building common areas

$EIBUA_g$ = **building_square_feet_industrial_gross:** Total industrial building square feet (built up area), including common areas

EIE_{perc} = **industrial_percent_efficiency:** The percent of building_square_feet_industrial_gross that is leasable to tenants

building_square_feet_agriculture_net

The leasable agricultural portion of building, excluding indoor building common areas.

Equation 3-42: building_square_feet_agriculture_net calculation

$$EAGBUA_n = EAGBUA_g * EAGE_{perc}$$

where:

$EAGBUA_n$ = **building_square_feet_agriculture_net:** The amount of a building in agricultural usage, excluding indoor building common areas

$EAGBUA_g$ = **building_square_feet_agriculture_gross:** Total agricultural building square feet (built up area), including common areas

$EAGE_{perc}$ = **agriculture_percent_efficiency:** The percent of building_square_feet_agriculture_gross that is leasable to tenants

building_square_feet_armed_forces_net

After excluding building common areas, the remainder of a building used for armed forces employees.

Equation 3-43: building_square_feet_armed_forces_net calculation

$$EAFBUA_n = EAFBUA_g * EAFE_{perc}$$

where:

$EAFBUA_n$ = **building_square_feet_armed_forces_net:** The amount of a building contained within armed forces uses, excluding indoor building common areas

$EAFBUA_g$ = **building_square_feet_armed_forces_gross:** Total armed forces building square feet (built up area), including common areas

$EAFE_{perc}$ = **armed_forces_percent_efficiency:** The percent of building_square_feet_armed_forces_gross contained within armed forces uses, excluding indoor building common areas

building_square_feet_detached_single_family

The total square feet of single family detached homes is the sum of small lot and large lot single family detached home square footage.

Equation 3-44: building_square_feet_detached_single_family calculation

$$RSF_{sf} = RSFLL_{sf} + RSFSL_{sf}$$

where:

RSF_{sf} = **building_square_feet_detached_single_family:** Total building square feet in single family detached homes

$RSFLL_{sf}$ = **building_square_feet_detached_single_family_large_lot:** Building square feet of detached single family large lot homes

$RSFSL_{sf}$ = **building_square_feet_detached_single_family_small_lot:** Building square feet of detached single family small lot homes

building_square_feet_detached_single_family_large_lot

The total square feet of single family detached large lot homes is derived from the total number of single family detached large lot DU and the average square feet per SFLLDU.

Equation 3-45: building_square_feet_detached_single_family_large_lot calculation

$$RSFLL_{sf} = SFLL_{d} * DU_{sfa}$$

where:

$RSFLL_{sf}$ = **building_square_feet_detached_single_family_large_lot:** Building square feet of detached single family large lot homes

$SFLL_{d}$ = **detached_single_family_large_lot_density:** Density of detached single family large lot dwelling units on total parcel acres

DU_{sfa} = **square_feet_per_du_average:** Square feet per large lot single family detached dwelling unit (average) [input]

building_square_feet_detached_single_family_small_lot

The total square feet of single family detached small lot homes is derived from the total number of single family detached small lot DU and the average square feet per SFSLDU.

Equation 3-46: building_square_feet_detached_single_family_small_lot calculation

$$RSFSL_{sf} = SFSL_{d} * DU_{sfa}$$

where:

$RSFSL_{sf}$ = **building_square_feet_detached_single_family_small_lot:** Building square feet of detached single family small lot homes

$SFSL_d$ = **detached_single_family_small_lot_density:** Density of detached single family small lot dwelling units on total parcel acres

DU_{sfa} = **square_feet_per_du_average:** Square feet per small lot single family detached dwelling unit (average) [input]

building_square_feet_attached_single_family

The total square feet of single family attached homes is derived from the total number of single family attached DU and the average square feet per attached DU.

Equation 3-47: building_square_feet_attached_single_family calculation

$$RTH_{sf} = TH_d * DU_{sfa}$$

where:

RTH_{sf} = **building_square_feet_attached_single_family:** Building square feet of attached single family homes

TH_d = **attached_single_family_density:** Density of attached single family dwelling units on total parcel acres

DU_{sfa} = **square_feet_per_du_average:** Square feet per attached single family dwelling unit (average) [input]

building_square_feet_multifamily

The total square feet of multifamily housing is derived from the total number of multifamily DU and the average square feet per multifamily DU.

Equation 3-48: building_square_feet_multifamily calculation

$$RMF_{sf} = MF_d * DU_{sfa}$$

where:

RMF_{sf} = **building_square_feet_multifamily:** Building square feet of multifamily housing

MF_d = **multifamily_density:** Density of multifamily dwelling units on total parcel acres

DU_{sfa} = **square_feet_per_du_average:** Square feet per multifamily dwelling unit (average) [input]

building_square_feet_residential_commons

The non-leasable portion of a residential building; that is, the amount contained within indoor residential common areas, outside of private dwelling units. This is calculated based on total gross residential built up area and the residential percent efficiency.

Equation 3-49: building_square_feet_residential_commons calculation

$$RCA_{sf} = RBUA_g * (1 - RE_{perc})$$

where:

RCA_{sf} = **building_square_feet_residential_commons:** Residential common area square feet

$RBUA_g$ = **residential_building_square_feet_gross:** Total residential building square feet (built up area), including common areas

RE_{perc} = **residential_percent_efficiency:** The percent of residential_building_square_feet_gross that is leasable to tenants

parcel_acres and parcel_square_feet

Parcel_acres, otherwise known as developable land (acres), can be derived in at least three different ways. It can be "sensed" from GIS data, actually describing the amount of acreage contained within a parcel or parcels within a study area. It can be derived based directly on urban form characteristics, for instance by multiplying block length by block width. Or, it can be derived based on a net-to-gross ratio, which in turn can be calculated based on one of the above two methods (or by other methodology). Parcel_square_feet is derived directly from parcel_acres by converting from acres to square feet.

Equation 3-50: parcel_acres calculation from gross_net_ratio

$$PA_{ac} = GN_R * L_{ac}$$

where:

PA_{ac} = **parcel_acres:** Total parcel acres

GN_r = **gross_net_ratio:** The ratio of developable to total land.

L_{ac} = **total_land_acres:** Total land; for the purpose of hypothetical place types, is generally equal to a single acre (1).

Equation 3-51: parcel_square_feet calculation

$$PA_{sf} = C_{sfac} * PA_{ac}$$

where:

PA_{sf} = **parcel_square_feet:** Total parcel square feet

PA_{ac} = **parcel_acres:** Total parcel acres

C_{sfac} = **square_feet_per_acre:** Square feet per acre (conversion factor; 43,560:1)

parcel_acres_residential

The total acres of parcels containing only residential uses is calculated by summing the area of parcels containing buildings with only residential uses.

Equation 3-52: parcel_acres_residential calculation

$$PAR_{ac} = L_{ac} * \sum PR_{perc}$$

where:

PAR_{ac} = **parcel_acres_residential:** Total acres of residential-only parcels

L_{ac} = **total_land_acres:** Total land; for the purpose of hypothetical place types, is generally equal to a single acre (1).

PR_{perc} = **residential_parcel_percentage:** The percentage of developable acres allocated to each building type that represents parcels containing only residential uses.

parcel_acres_residential_detached_single_family_large_lot

The total acres of parcels containing only residential single family large lot development is calculated by summing the area of large-lot parcels containing single family buildings.

Equation 3-53: parcel_acres_residential_detached_single_family_large_lot calculation

$$PARSFLL_{ac} = L_{ac} * \sum PRSFLL_{perc}$$

where:

$PARSFLL_{ac}$ = **parcel_acres_residential_detached_single_family_large_lot:** Total acres of single family residential large lot parcels

L_{ac} = **total_land_acres:** Total land; for the purpose of hypothetical place types, is generally equal to a single acre (1).

$PRSFLL_{perc}$ = **residential_detached_single_family_large_lot_parcel_percentage:** The percentage of developable acres allocated to each single family building type that represents large lot parcels.

parcel_acres_residential_detached_single_family_small_lot

The total acres of parcels containing only residential single family small lot development is calculated by summing the area of small-lot parcels containing single family buildings.

Equation 3-54: parcel_acres_residential_detached_single_family_small_lot calculation

$$PARSFSL_{ac} = L_{ac} * \sum PRSFSL_{perc}$$

where:

$PARSFSL_{ac}$ = **parcel_acres_residential_detached_single_family_small_lot:** Total acres of single family residential small lot parcels

L_{ac} = **total_land_acres:** Total land; for the purpose of hypothetical place types, is generally equal to a single acre (1).

$PRSFSL_{perc}$ = **residential_detached_single_family_small_lot_parcel_percentage:** The percentage of developable acres allocated to each single family building type that represents small lot parcels containing only residential uses.

parcel_acres_residential_attached_single_family

The total acres of parcels containing only attached residential single family development is calculated by summing the area of parcels containing single family attached buildings.

Equation 3-55: parcel_acres_residential_attached_single_family calculation

$$PARSFTH_{ac} = L_{ac} * \sum PRSFTH_{perc}$$

where:

$PARSFTH_{ac}$ = **parcel_acres_residential_attached_single_family:** Total acres of single family attached residential parcels

L_{ac} = **total_land_acres:** Total land; for the purpose of hypothetical place types, is generally equal to a single acre (1).

$PRSFTH_{perc}$ = **residential_attached_single_family_parcel_percentage:** The percentage of developable acres allocated to parcels containing single family attached building types.

parcel_acres_residential_multifamily

The total acres of parcels containing residential multifamily development is calculated by summing the area of parcels containing multifamily buildings.

Equation 3-56: parcel_acres_residential_multifamily calculation

$$PARMF_{ac} = L_{ac} * \sum PRMF_{perc}$$

where:

$PARMR_{ac}$ = **parcel_acres_residential_multifamily:** Total acres of multifamily residential parcels

L_{ac} = **total_land_acres:** Total land; for the purpose of hypothetical place types, is generally equal to a single acre (1).

$PRMF_{perc}$ = **residential_multifamily_parcel_percentage:** The percentage of developable acres allocated to parcels containing multifamily building types.

parcel_acres_employment

The total acres of parcels containing only employment uses is calculated by summing the area of parcels containing buildings with only employment uses.

Equation 3-57: parcel_acres_employment calculation

$$PAE_{ac} = L_{ac} * \sum PE_{perc}$$

where:

PAE_{ac} = **parcel_acres_employment:** Total acres of employment-only parcels

L_{ac} = **total_land_acres:** Total land; for the purpose of hypothetical place types, is generally equal to a single acre (1).

PE_{perc} = **employment_parcel_percentage:** The percentage of developable acres allocated to each building type that represents parcels containing only employment uses.

parcel_acres_employment_office

The total acres of parcels containing office employment development is calculated by summing the area of parcels containing buildings with an office use.

Equation 3-58: parcel_acres_employment_office calculation

$$PAEO_{ac} = L_{ac} * \sum PEO_{perc}$$

where:

$PAEO_{ac}$ = **parcel_acres_employment_office:** Total acres of office employment parcels

L_{ac} = **total_land_acres:** Total land; for the purpose of hypothetical place types, is generally equal to a single acre (1).

PEO_{perc} = **employment_office_parcel_percentage:** The percentage of developable acres allocated to parcels containing building types with an office use.

parcel_acres_employment_retail

The total acres of parcels containing retail employment development is calculated by summing the area of parcels containing buildings with a retail use.

Equation 3-59: parcel_acres_employment_retail calculation

$$PAER_{ac} = L_{ac} * \sum PER_{perc}$$

where:

$PAER_{ac}$ = **parcel_acres_employment_retail:** Total acres of retail employment parcels

L_{ac} = **total_land_acres:** Total land; for the purpose of hypothetical place types, is generally equal to a single acre (1).

PER_{perc} = **employment_retail_parcel_percentage:** The percentage of developable acres allocated to parcels containing building types with a retail use.

parcel_acres_employment_industrial

The total acres of parcels containing industrial employment development is calculated by summing the area of parcels containing buildings with an industrial use.

Equation 3-60: parcel_acres_employment_industrial calculation

$$PAEI_{ac} = (L_{ac} * \sum PEI_{perc})$$

where:

$PAEI_{ac}$ = **parcel_acres_employment_industrial:** Total acres of industrial employment parcels

L_{ac} = **total_land_acres:** Total land; for the purpose of hypothetical place types, is generally equal to a single acre (1).

PEI_{perc} = **employment_industrial_parcel_percentage:** The percentage of developable acres allocated to parcels containing building types with an industrial use.

parcel_acres_employment_agricultural

The total acres of parcels containing agricultural employment development is calculated by summing the area of parcels containing buildings with an agricultural use.

Equation 3-61: parcel_acres_employment_agricultural calculation

$$PAEAG_{ac} = L_{ac} * \sum PEAG_{perc}$$

where:

$PAEAG_{ac}$ = **parcel_acres_employment_agricultural:** Total acres of agricultural employment parcels

L_{ac} = **total_land_acres:** Total land; for the purpose of hypothetical place types, is generally equal to a single acre (1).

$PEAG_{perc}$ = **employment_agricultural_parcel_percentage:** The percentage of developable acres allocated to parcels containing building types with an agricultural use.

parcel_acres_employment_armed_forces

The total acres of parcels containing armed forces employment development is calculated by summing the area of parcels containing buildings with an armed forces use. Note: Version 1.0 of UrbanFootprint does not include armed forces as an employment category coming from built form that can be painted in the future; however, at UrbanFootprint v1.1 it will be added to the schema.

Equation 3-62: parcel_acres_employment_armed_forces calculation

$$PAEAF_{ac} = L_{ac} * \sum PEAF_{perc}$$

where:

$PAEAF_{ac}$ = **parcel_acres_employment_armed_forces:** Total acres of armed forces employment parcels

L_{ac} = **total_land_acres:** Total land; for the purpose of hypothetical place types, is generally equal to a single acre (1).

$PEAF_{perc}$ = **employment_armed_forces_parcel_percentage:** The percentage of developable acres allocated to parcels containing building types with an armed forces use.

parcel_acres_employment_mixed

The total acres of parcels containing a mix of employment uses is calculated by summing the area of parcels containing buildings with a mix of employment uses.

Equation 3-63: parcel_acres_employment_mixed calculation

$$PAEM_{ac} = L_{ac} * \sum PEM_{perc}$$

where:

$PAEM_{ac}$ = **parcel_acres_employment_mixed:** Total acres of mixed employment parcels

L_{ac} = **total_land_acres:** Total land; for the purpose of hypothetical place types, is generally equal to a single acre (1).

PEM_{perc} = **employment_mixed_parcel_percentage:** The percentage of developable acres allocated to parcels containing building types with a mix of employment uses.

parcel_acres_mixed_use

The total acres of parcels containing a mix of residential and employment uses is calculated by summing the area of parcels containing buildings with both residential and employment uses.

Equation 3-64: parcel_acres_mixed_use calculation

$$PAMU_{ac} = L_{ac} * \sum PMU_{perc}$$

where:

$PAMU_{ac}$ = **parcel_acres_mixed_use:** Total acres of mixed use parcels

L_{ac} = **total_land_acres:** Total land; for the purpose of hypothetical place types, is generally equal to a single acre (1).

PMU_{perc} = **mixed_use_parcel_percentage:** The percentage of developable acres allocated to each building type that represents parcels containing a mix of residential and employment uses.

parcel_acres_mixed_use_with_office

The total acres of parcels containing a mix of residential and employment uses, including office employment, is calculated by summing the area of parcels containing buildings with a mix of residential and employment uses with more than zero office employees.

Equation 3-65: parcel_acres_mixed_use_with_office calculation

$$PAMUO_{ac} = L_{ac} * \sum PMO_{perc}$$

where:

$PAMUO_{ac}$ = **parcel_acres_mixed_use_with_office:** Total acres of mixed residential and employment (including office) parcels

L_{ac} = **total_land_acres:** Total land; for the purpose of hypothetical place types, is generally equal to a single acre (1).

PMO_{perc} = **mixed_use_with_office_parcel_percentage:** The percentage of developable acres allocated to parcels containing building types with a mix of residential and employment uses (including office).

parcel_acres_mixed_use_no_office

The total acres of parcels containing a mix of residential and employment uses, excluding office employment, is calculated by summing the area of parcels containing buildings with a mix of residential and employment uses with no office employees.

Equation 3-66: parcel_acres_mixed_use_no_office calculation

$$PAMUNO_{ac} = L_{ac} * \sum PMNO_{perc}$$

where:

$PAMUNO_{ac}$ = **parcel_acres_mixed_use_no_office:** Total acres of mixed residential and employment (no office) parcels

L_{ac} = **total_land_acres:** Total land; for the purpose of hypothetical place types, is generally equal to a single acre (1).

$PMNO_{perc}$ = **mixed_use_no_office_parcel_percentage:** The percentage of developable acres allocated to parcels containing building types with a mix of residential and employment uses (excluding office).

hardscape_percentage [input]

The percent of a parcel that is covered by hardscape, including buildings and non-permeable paved areas. The inverse of this percentage refers to the landscape or pervious-surface percentage.

roof_impervious_percentage [input]

The percent of a parcel that is covered by impervious building roofing. Unless there is a green (pervious) roof present, this is equal to the percent of a parcel covered by building roofs.

hardscape_pervious_percentage [input]

The percent of a parcel that is covered by pervious hardscape, including permeable paved areas and green roofs.

softscape_percentage [input]

The percent of a parcel that is covered by softscape, including landscaping and undeveloped (permeable or naturally impermeable) portions of the lot. This is the inverse of the hardscape percentage.

irrigated_percentage [input]

Refers to the percent of the softscape percentage that is irrigated. That is, excluding the hardscape (which includes buildings and non-permeable paved areas), the percent of the landscaped/permeable portion of a parcel that receives irrigation.

residential_square_feet_irrigated

The total square feet of irrigated yard on residential parcels; calculated by multiplying the softscape percentage by the irrigated percentage for each participating residential building, then converting from acres to square feet.

Equation 3-67: residential_square_feet_irrigated calculation

$$IR_{sf} = PAR_{ac} * S_{perc} * I_{perc} * \ C_{sfac}$$

where:

IR_{sf} = **residential_square_feet_irrigated:** Total square feet of irrigated residential yard

PAR_{ac} = **parcel_acres_residential:** Total acres of residential-only parcels

C_{sfac} = **square_feet_per_acre:** Square feet per acre (conversion factor; 43,560:1)

S_{perc} = **softscape_percentage:** The percent of a parcel that is covered by softscape, including landscaping and undeveloped (permeable or naturally impermeable) portions of the lot.

I_{perc} = **irrigated_percentage:** The percentage of the softscape area of a parcel that is irrigated.

employment_square_feet_irrigated

The total square feet of irrigated landscaping on employment parcels; calculated by multiplying the softscape percentage by the irrigated percentage for each participating employment building, then converting from acres to square feet.

Equation 3-68: employment_square_feet_irrigated calculation

$$IE_{sf} = PAR_{ac} * S_{perc} * I_{perc} * \ C_{sfac}$$

where:

IE_{sf} = **employment_square_feet_irrigated:** Total square feet of irrigated employment landscaping

PAE_{ac} = **parcel_acres_employment:** Total acres of employment-only parcels

C_{sfac} = **square_feet_per_acre:** Square feet per acre (conversion factor; 43,560:1)

S_{perc} = **softscape_percentage:** The percent of a parcel that is covered by softscape, including landscaping and undeveloped (permeable or naturally impermeable) portions of the lot.

I_{perc} = **irrigated_percentage:** The percentage of the softscape area of a parcel that is irrigated.

land_percentage_mixed_use

The percentage of total acres containing a mix of residential and employment parcels; this is calculated based on total area and the area of parcels containing buildings with both residential and employment uses.

Equation 3-69: land_percentage_mixed_use calculation

$$LMU_{perc} = PAMU_{ac}/L_{ac}$$

where:

LMU_{perc} = **land_percentage_mixed_use:** Mixed use parcels as a percentage of total land

L_{ac} = **total_land_acres:** Total land; for the purpose of hypothetical place types, is generally equal to a single acre (1).

$PAMU_{ac}$ = **parcel_acres_mixed_use:** Total acres of mixed use parcels

land_percentage_residential

The percentage of total acres containing solely residential parcels; this is calculated based on total area and the area of parcels containing buildings with residential-only uses.

Equation 3-70: land_percentage_residential calculation

$$LR_{perc} = PAR_{ac}/L_{ac}$$

where:

LR_{perc} = **land_percentage_residential:** Residential parcels as a percentage of total land

L_{ac} = **total_land_acres:** Total land; for the purpose of hypothetical place types, is generally equal to a single acre (1).

PAR_{ac} = **parcel_acres_residential:** Total acres of residential parcels

land_percentage_employment

The percentage of total acres containing solely employment parcels; this is calculated based on total area and the area of parcels containing buildings with employment-only uses.

Equation 3-71: land_percentage_employment calculation

$$LE_{perc} = PAE_{ac}/L_{ac}$$

where:

LE_{perc} = **land_percentage_employment:** Employment parcels as a percentage of total land

L_{ac} = **total_land_acres:** Total land; for the purpose of hypothetical place types, is generally equal to a single acre (1).

PAE_{ac} = **parcel_acres_employment:** Total acres of employment parcels

urban_land_development_category

The urban Land Development Category (LDC) occurs within an urban design context including more than 150 walkable street intersections per square mile for a place type. It also features a high amount of residential and employment density, supported by frequent transit service. Residences tend to be townhomes or multifamily units; employment tends to be in buildings with an FAR higher than 0.5, and frequently higher than 1.0. The intent of the urban LDC is to describe the most walkable, transit-oriented, low-vehicle-miles-traveled (VMT) city environments. This LDC categorization is utilized by UrbanFootprint's version 1.0 fiscal impacts model.

compact_land_development_category

The compact Land Development Category (LDC) occurs within an urban design context including more than 150 walkable street intersections per square mile for a place type. Residential and employment densities are lower than the urban LDC, and can be supported by transit service of varying quality. Residences tend to be a mix of single family, townhome and multifamily units; employment tends to be in mixed-use buildings with an FAR higher than 0.5, and sometimes higher than 1.0. The intent of the compact LDC is to describe walkable, somewhat-transit-oriented, low-to-medium-VMT neighborhood environments. This LDC categorization is utilized by UrbanFootprint's version 1.0 fiscal impacts model.

standard_land_development_category

The standard Land Development Category (LDC) occurs within an urban design context including less than 150 walkable street intersections per square mile for a place type. Residential and employment densities tend to be lower than in compact or urban LDCs, and are oriented towards the automobile as the primary mode of transportation. Residences tend to be single family, though townhome and multifamily units also occur; employment tends to be in single-use buildings with an FAR lower than 0.5, and sometimes lower than .35. The intent of the standard LDC is to describe less-walkable, automobile-oriented, medium-to-high-VMT suburban environments. This LDC categorization is utilized by UrbanFootprint's version 1.0 fiscal impacts model.

CHAPTER 4

Scenario Creation

Scenarios can be created in two ways in UrbanFootprint: translation of existing plans or 'painting' a new scenario from scratch. The building blocks of future scenarios in UrbanFootprint are place types, which populate a future scenario with attributes representing change areas (in future versions, the direct application of building types to parcels will also be used to describe change areas). UrbanFootprint models a future by combining a place typed canvas of change areas with base parcels which are slated for conversion to future place types, and passing through base attributes for non-change areas. This merging of future, developing, and base geographies and attributes is undertaken in the UrbanFootprint scenario core module. This section details the UrbanFootprint functionality and methodologies used for creating future scenarios.

Existing Plan Translation

UrbanFootprint includes tools that quickly translate any existing plan or scenario into the model's common language of place and building types. The model can translate jurisdictional, county, regional, and other plans, no matter what tool or process was used to create them. The five variables required for translation into the UrbanFootprint place type framework are:

- Density of dwelling units per acre
- Density of employees per acre
- % of employment that is retail
- % of employment that is office + industrial
- Walkable street intersections per square mile

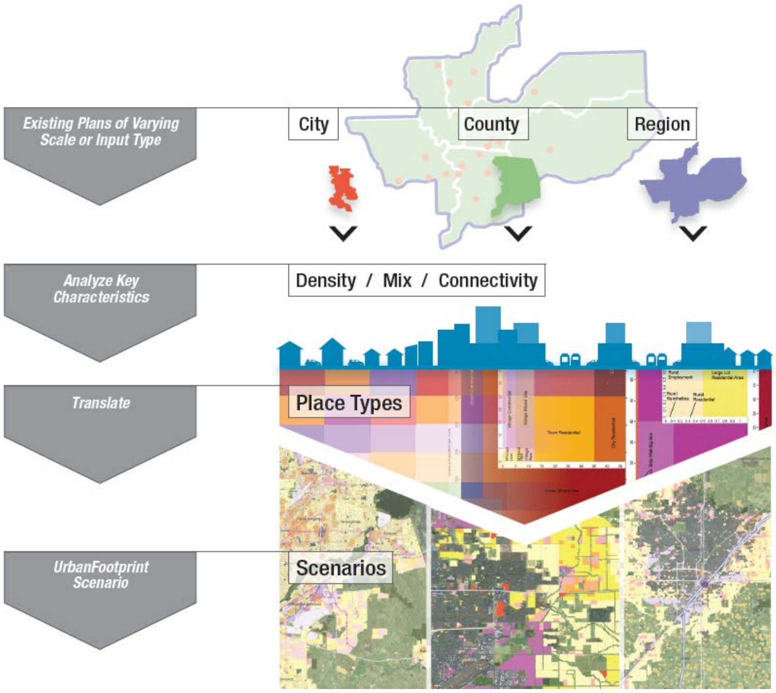


Figure 4-1: Plan Translation Diagram

Translation utilizes pre-defined density ranges for each place type, which are intended to cover every potential combination of the required input attributes. The translation engine processes every possible combination for each unit of analysis and returns the associated place type.

Once an existing plan is translated into UrbanFootprint, additional editing or scenario painting can be performed using the web based graphical interface, and analytical engines can be run to produce performance measures. The translation tools also provide the capacity to maintain a common “quilt” of local land use and transport plans, and to perform consistent, compatible analysis on individual plans or combinations thereof.

At the state and regional levels, UrbanFootprint translation functionality can be used to integrate or stitch together Sustainable Community Strategies (SCSs), Regional Transportation Plans (RTPs) or similar regional plans, and general/local-scale plans as they are produced. This comprehensive plans database can be made available to local governments looking to coordinate their land-use assumptions with other localities and regions for SCS/regional planning and analysis.

Scenario Painting and Editing

UrbanFootprint's web-based painting tool is integrated into the model's graphical user interface. It allows the user to edit a translated plan or create a new scenario from scratch. The web-based scenario painter can display regularly updated base maps and data available on the web today (e.g., Google Maps, Mapquest, Bing, OpenStreetMap), in addition to scenario- or project-specific data or imagery. The scenario painter's tools enable quick painting and editing of place types (at version 1.0; building types will also be paint-able in future versions), and dynamic viewing of scenario results. The current version (1.0) of the model utilizes the 5.5-acre (150m x 150m) grid cell as the unit of painting and analysis.

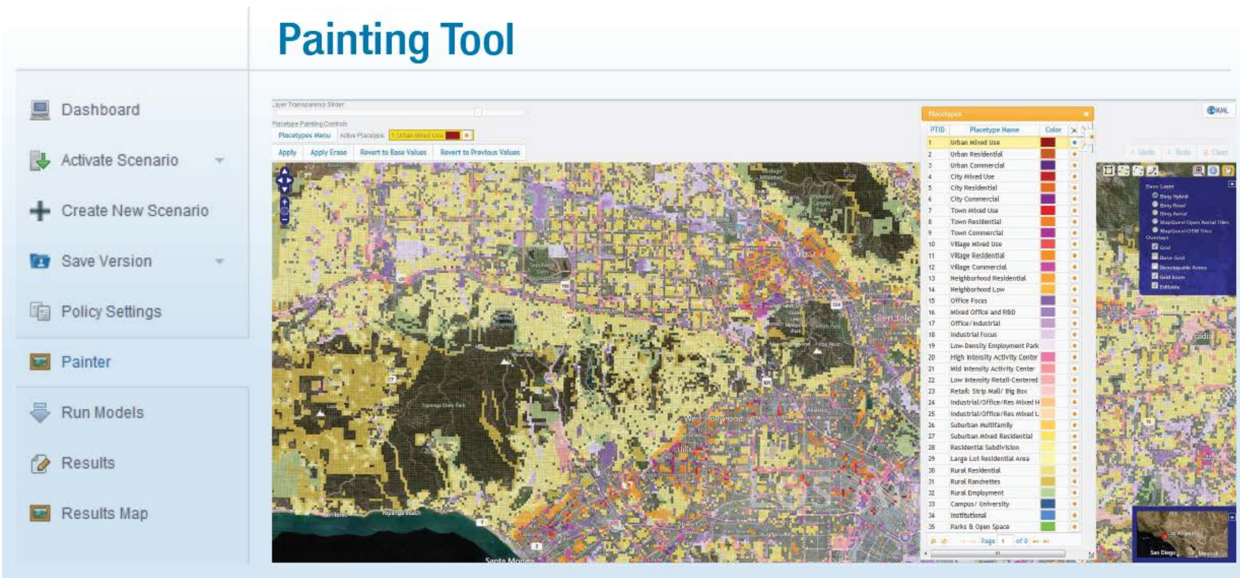


Figure 4-2: UrbanFootprint v1.0 Web-Based Painting Tool

CHAPTER 5
Scenario Core Processes

UrbanFootprint's scenario development and analytical engines produce a wide range of inter-related metrics that allow for meaningful comparisons of alternative land use and transportation scenarios. A series of scenario 'core' processes work to combine the existing physical and demographic environment with change or growth input via existing plans and/or newly painted scenarios. These core processes include:

- **Developable Lands Filter:** otherwise known as the "Developable Acres Analysis"; a pre-process that allows the user to select which types of parcels are developable or undevelopable, for the purpose of constraining where future growth can happen; can also be replaced by importing a user-defined set of developable (or undevelopable) parcels (or other type of geography).
- **Scenario Core:** combines future change areas (described with place types at version 1.0 and with place or building types in future versions) with no-change areas (coming from the loaded base year data) to produce scenario attributes for the horizon year.
- **Demographics Engines:** produces estimates of household income based on changes in urban form and affordability criteria similar to those used by the Federal Housing Administration (FHA) to determine homeowner mortgage eligibility

The output of the core processes becomes the input to UrbanFootprint's other model engines (see Figure 5-1), to measure scenario performance for energy & water consumption, GHG emissions, travel behavior and other indicators.

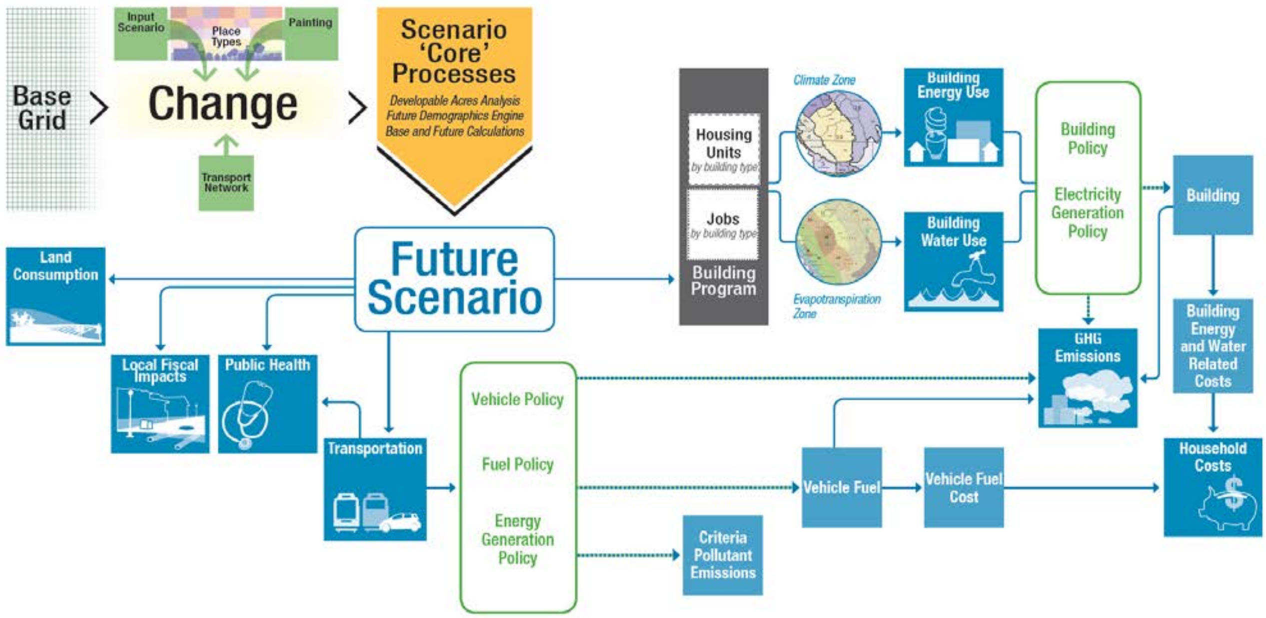


Figure 5-1: UrbanFootprint v1.0 Model Diagram

Developable Lands Filter

As a preparatory step prior to the creation of future scenarios, UrbanFootprint requires that the base environment be classified into "change" and "no-change" areas. "Change" areas define where in the existing-year base new growth can occur in the future; "no-change" areas are those areas designated as constrained from receiving new growth. At version 1.0 of UrbanFootprint, the developable lands filter classifies whole parcels as "change" or "no-change," either by applying a filter based on parcel attributes or by utilizing a predefined redevelopment analysis that is uploaded by the user. The output of the developable lands filter is a table at the grid cell scale that contains the amount of land available to receive the attributes of a place type when it is painted (or assigned via the translation process).

As noted previously, at UrbanFootprint v1.0, the developable lands filter operates in one of two ways:

- The user can import an existing assessment of parcels capable of receiving development (as in a redevelopment analysis that flags specific parcels as able to receiving new or additional development)
- If no preexisting assessment is available, the user can select which categories of parcels to exclude from development; all other types of parcels (excluding environmentally constrained areas) are then considered developable and are added to the count of developable acres within each grid cell. The categories of parcels for which development can be excluded are:
    - All Urban Residential Parcels
    - All Urban Residential Detached Single Family Parcels
    - Urban Residential Detached Single Family Small Lot Parcels
    - Urban Residential Detached Single Family Large Lot Parcels
    - Urban Residential Multifamily Parcels
    - All Urban Employment Parcels

- Urban Office Employment Parcels
- Urban Retail Employment Parcels
- Urban Industrial Parcels
- Urban Agriculture Parcels
- Urban Mixed Employment Parcels (No Residential)
- All Urban Mixed Use Parcels
- Urban Mixed Use Parcels with Office
- Urban Mixed Use Parcels, Retail Only
- Urban Parcels with No Use
- Greenfield Parcels

Once a set of parcel types to exclude from development is selected, the developable lands engine cross-references against the loaded base year data to determine the demographic attributes of the developable acres within each grid cell. These attributes will be subtracted from the attributes of the place type to produce the net impact of painting that place type on that grid cell. See the section of this document entitled "The Scenario Core: Base + Future Calculations" for more information on this process.

Developable Lands Table

The output of the Developable Lands Filter is a table that contains base attributes for geographies identified as change areas by the filter, or a user defined redevelopment analysis. All geographies which are not candidates for change will contain zeros in the output table, which when painted with place type densities, will not allow those geographies to receive future units (dwelling units or employment).

The Scenario Core: Base + Future Calculations

The scenario core populates the end state and associated scenario increment tables with scenario attributes which can be used as inputs for further scenario metrics or visualized as representations of the scenario itself. The scenario core joins the associated place type densities with each place type in the scenario canvas, calculates new scenario attributes, and combines change areas and units with the base environment. The result of the scenario core being run is the production of a future scenario with the primary fields of dwelling units by type, employment by type, building square footage by type and acreage by type. The scenario core produces a future scenario with most of the necessary fields to be run through UrbanFootprint's analytical engines to measure and compare scenario performance. Figure 5-2 outlines the general process that scenario core utilizes.

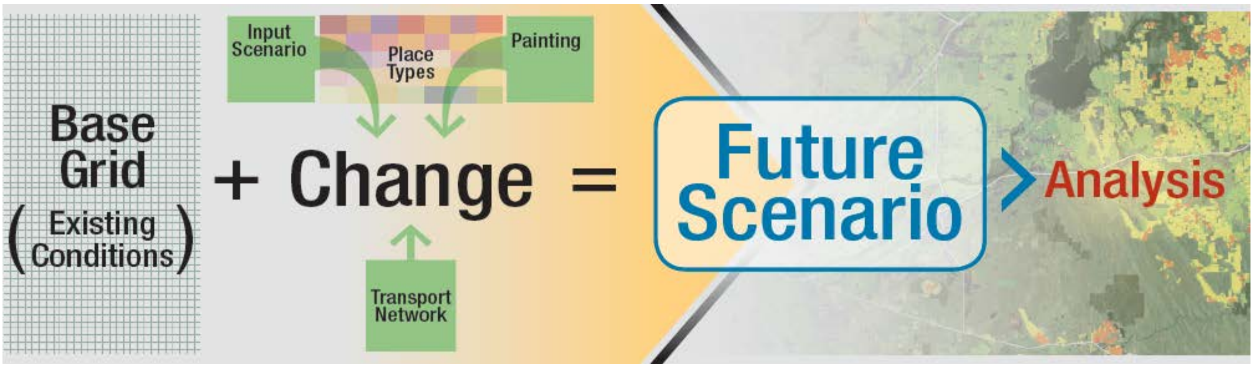


Figure 5-2: The UrbanFootprint v1.0 Scenario Core Combines Base + Change to Create the Future Scenario

The UrbanFootprint scenario core maintains the important distinction between areas that do or do not change in a future scenario. This depiction of the future as a combination of "change" and "no-change" areas is significant, as physical changes in the urban form of change areas can impact behavior in adjacent no-change areas. UrbanFootprint estimates travel and other impacts of these conditions (e.g., where infill or new development occurs around but not directly within a district or neighborhood, or where parcels receiving infill development are surrounded by parcels that remain the same as in the base year). It also allows for validation of the many analytical engines in the UrbanFootprint model, as model outputs can be compared to and calibrated against known qualities (using empirical data about existing conditions) and other model depictions of the existing/base environment.

Scenario Core Input Tables

The scenario core utilizes a number of input tables to produce a future scenario. These input tables include:

- **Scenario Canvas:** The table containing place type IDs derived either from scenario translation or from the painting tool.
- **Place Type Attribute Table:** A table containing the unique IDs for each place type and the associated densities for each field.
- **Developable Lands Table:** The developable lands table containing the filtered base fields either through a user-defined filter or an uploaded redevelopment analysis.
- **Loaded Base Table:** The loaded base table with all fields created through the base load process.

Scenario Core Methodology

The methods employed in the scenario core produce a future scenario table, a gross increment table, and a net increment table. The methods to produce these tables are detailed in this section.

Step 1: Create gross increment table. The gross increment table represents all new units in change areas laid down by place types. The first pass in producing the gross increment table is joining the place type attribute table to the scenario canvas on their place type ID. The second pass joins the Developable lands table to the scenario canvas of the primary key (in v1.0 this is the grid ID). The final pass calculates each of the fields that populate the gross increment table. The calculation for each field follows the same pattern and logic which is detailed in Equation 5-1:

Equation 5-1: Gross Increment Calculation

$If\ refill\ flag = True$

$$F_h = F_{PTn} * D_{pct} * Ac_n$$

$If\ refill\ flag = False$

$$F_h = F_{PTg} * D_{pct} * Ac_g$$

Where:

$refill\ flag = Boolean\ flag\ identifying\ if\ scenario\ row\ is\ flagged\ as\ refill\ or\ greenfield$

$F_h = Field\ value\ for\ field\ h\ in\ the\ gross\ increment\ table$

$F_{PTg} = Gross\ place\ type\ density\ \left(\frac{units}{acre}\right) for\ field\ h\ from\ place\ type\ attribute\ table$

$F_{PTn} = Net\ place\ type\ density\ \left(\frac{units}{acre}\right) for\ field\ h\ from\ place\ type\ attribute\ table$

$D_{pct} = Development\ percentage$

$Ac_n = Net\ developable\ acreage\ from\ the\ developable\ lands\ table$

$$Ac_g = Gross\ developable\ acreage\ from\ developable\ lands\ table$$

Step 2: Create core scenario table. The scenario core table represents the end state scenario with all of the change attributes merged with no-change base attributes. The process for producing the scenario table joins the gross increment table, the developable lands table, and the loaded base table on their primary keys. The fields are then calculated, all of which follow the same pattern that is detailed in Equation 5-2.

Equation 5-2: End State Core Calculation

$$F_{hS} = F_{hG} - F_{hD} + F_{hB}$$

Where:

$F_{hS} = Value\ for\ field\ h\ in\ the\ core\ scenario\ table$

$F_{hG} = Value\ for\ field\ h\ in\ the\ gross\ increment\ table$

$F_{hD} = Value\ for\ field\ h\ in\ the\ developable\ lands\ table$

$F_{hB} = Value\ for\ field\ h\ in\ the\ loaded\ base\ table$

Step 3: Create net increment table. The net increment table represents the net change in a scenario as a result of applying place types and the redevelopment of base year units and attributes . The net increment of the different scenario attributes is a key dataset for tuning and editing a future scenario. Each field is calculated using the same logic using Equation 5-3.

Equation 5-3: Net Increment Calculation

$$F_{hN} = F_{hS} - F_{hB}$$

Where:

$$F_{hN} = Value\ for\ field\ h\ in\ the\ net\ increment\ table$$

$$F_{hS} = Value\ for\ field\ h\ in\ the\ core\ scenario\ table$$

$$F_{hB} = Value\ for\ field\ h\ in\ the\ loaded\ base\ table$$

Scenario Core Output Tables

The three primary output tables of the scenario core provide the necessary layers for scenario assessment in terms of mix of dwelling units, employment, and built form. They form the primary inputs to a range of scenario analysis engines and can also be used for direct visualizations of the scenarios they represent. The output tables of the scenario core are:

- **End State Core Table:** The end state core table is the result of merging the future change with the base change and no change areas. It is a full coverage table of the study regions.
- **Gross Increment Table:** The gross increment table represents only the change areas and the gross change attributes. Gross change includes all new units without including those units that were removed due to the redevelopment.
- **Net Increment Table:** The net increment table reflects the net change in a scenario, accounting for the number of base units that redeveloped in the change calculation. The net increment table is important for constructing a scenario and understanding how change is being applied to the base.

Demographics Engines

The methodology for estimating future demographics for the model, in particular income, is based on the urban form of future housing units, cross-referenced with a basic understanding of market forces and prices in the California for-sale and rental housing markets. The need for UrbanFootprint to directly predict future demographics, in particular income, arises because there is no other available known data source that makes this kind of estimation at the resolution required for the operation of the model and its analytical engines.

Predicting Income based on Urban Form of New Development

The fundamental methodology uses a basic understanding of housing affordability calculations to estimate minimum incomes required to afford new rental and ownership housing units, based on predictions or assumptions about the cost of those units founded on their urban form.

Values based on 2010 Fiscal Impacts Study

The initial version of this demographics engine uses an understanding of valuation based on urban form that flows from fiscal impacts analysis work performed by Strategic Economics in 2010. This work divided future growth into four Land Development Categories (LDCs): Urban, Compact-Refill, Compact-Greenfield, and Standard growth. Within each of the LDCs, four housing unit types (Large Lot Single Family Detached, Small Lot Single Family Detached, Single Family Attached, and Multifamily) were assigned a purchase price based on detailed studies of housing valuation within the state of California.

Ownership Units: Predicting income based on housing value

The relationship between housing value, urban form and income has been studied by Strategic Economics for the 2010 Fiscal Impacts study. With some assumptions, this basis allows income to be derived based on housing value averages by unit type and urban form. Traditional mortgage-underwriting standards indicate that total housing expenses should not consume more than 28% of a household's gross income.[4] If the unit being purchased is in an area that would allow it, by virtue of its proximity to transit, to qualify for a location-efficient mortgage, then total housing expenses could reasonably consume up to 39% of income[5]. Mortgage payments can be estimated using assumptions about the interest rate (4% is the default) and the term (30 years is the default). With some assumptions about taxes (1% annually of a home's purchase price) and insurance (0.5% annually), total housing expense assumptions can be produced. From these, using the affordability criteria matched to the presence (or lack) of high-quality transit, minimum incomes required to purchase each ownership unit can be derived.

Rental Units: Predicting income based on rent projections

If the purchase price of a unit is assumed, then certain additional assumptions could be made about the amount of profit that landlords wish to make off of the renting-out of that unit, and therefore the amount of rent per month for that unit can be predicted. The default assumption for the purpose of this module would be to assume that rents are set at 130% of the monthly mortgage payment amount for each unit. This represents a level high enough to provide a comfortable amount of profit (after expenses) to the landlord, but not so high as to be incompatible with the price level in the ambient rental market.[6]

If total housing expenses are then held to 28% of total household income (or 39% in areas that are location-efficient), then the minimum income required to afford the rental unit can be derived.

Deriving Number of Households by Income Class

By counting the numbers of units at each price point within each unit of analysis (i.e. 150m-square grid cell), the numbers of households within each income class ($10-20k/year, $20-30k/year, etc.) are derived.

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[4] From: http://www.nrdc.org/cities/smartgrowth/qlem.asp; also, OECD (2009), OECD Territorial Reviews: Toronto, Canada, OECD Publishing, Paris via **Regional Development Policies in OECD Countries.** By OECD - Organization for Economic Co-operation and Development, Paris, France 2010.

[5] While location-efficient mortgages are not yet codified into law at the state or federal level, they are used as a proxy for affordability and other policies that may bring down the cost of housing near transit from the levels that would otherwise be set by the market. The logic behind location-efficient mortgages is that households located close to high-quality transit are likely to spend less of their income on automobile-related expenditures, and thus have a higher percentage of their income available for housing-related expenditures. Even without the presence of a formalized location-efficient mortgage framework, this is a rational basis for assuming that households near high-quality transit can afford to spend a higher percentage of their income on housing than households located elsewhere.

[6] The 130% setting may need to be adjusted for future deployments of UrbanFootprint based on the outcomes of further study of the relationship between sales price and rent levels; it is based currently on empirical evidence from the San Francisco Bay Area. Future versions of UrbanFootprint may benefit from alternative calculations of rental prices based on the capitalized value of market rents.

Pivoting Values off of Average Regional Housing Value

To account for regional variations in housing value not picked up by the statewide study undertaken to calibrate the fiscal engine that this engine is based off of, the user must input the statewide average housing value. The statewide average is used to calculate the percentage of the average the housing value represents for each unit type and Land Development Category combination.

Adjusting Housing Values to the Local Housing Market

To account for local variations in land value, the set of regional housing values is further modified based on the relationship between the income in each grid cell and the overall regional average household income. This takes into account local variation in housing value for otherwise identical unit types. Regional average values per housing unit type by LDC and refill/greenfield class are adjusted up or down based on the difference from the regional average annual household income and the average annual household income of each individual grid cell being analyzed.

Percent of Units For Sale

The user can adjust the percentage of each unit type that is for sale (and thus, the inverse, what percentage are for the rental market) by LDC. Default values are 100% for sale for both single-family detached types, 73% for sale for townhomes, and 19% for sale for multi-family unit types.

Actual Income Values for Each Income Range for the base

The model adds income for future households to income for existing (base year) households in order to calculate the average and aggregate incomes for the study area for the future year. For each of the income ranges ($10-20k per year, $20-30k per year, etc.), the user can set the actual average value that is used by the model to calculate household incomes for the base. For instance, the model assumes by default that the average income for households in the range $10k to $20k is $18k; the user can simply put in a different value (say, $15k) if so desired.

Customize Housing Values by LDC and Type

The user can input the average housing value for the following unit types for each of the four LDCs:

- SF Small Lot Detached
- SF Large Lot Detached
- SF Attached/Townhome - For Sale
- Multi-Family - For Sale
- SF Attached/Townhome - Rental
- Multi-Family – Rental

Initial values come from the 2010 fiscal study performed by Strategic Economics; they are modified by region and by grid cell as described above.

Future Income Methodology

The general process for producing income related fields in UrbanFootprint relies on a classification of Place types into Land Development Categories (LDCs). Each place type contains a Boolean flag to identify which LDC it belongs and classifies any new dwelling units created by a place type to the associated LDC. As part of producing a new scenario in the Scenario Core, each grid cell is aware of the percentage of development that is occurring as refill or greenfield, and classifies new growth within each grid cell by the four LDC types and by greenfield or refill (Urban, Compact-Refill, Compact-Greenfield or Standard). Housing values are estimated for the four housing unit types based on the corresponding LDC and unit type combination. Income related fields are then derived from these values. The detailed methodology is as follows:

Step 1: Calculate average housing value by dwelling unit type, LDC, ownership/rental, and refill/greenfield. The calculations for housing value by dwelling unit type use the average housing values contained in Table 5-1. These housing values by type population fields in a temporary grid table that geographically adjusts housing values by the ratio of block group household average income to statewide average income. In this way, the average housing values by type at the grid cell scale are relative to localized incomes in the base year. The calculations are detailed in Equation 5-4.

Table 5-1: Average Housing Values by Land Development Category & Unit Type

Category	*Housing Type*	*Average Housing Value*
Statewide		
	Statewide Property Average	$495,000
Standard		
	SF Small Lot Detached	$281,700
	SF Large Lot Detached	$361,752
	SF Attached/Townhome - For Sale	$308,300
	Multi-Family - For Sale	$176,300
	SF Attached/Townhome - Rental	$314,000
	Multi-Family - Rental	$109,000
Compact-Greenfield		
	SF Small Lot Detached	$730,200
	SF Large Lot Detached	$935,394
	SF Attached/Townhome - For Sale	$427,000
	Multi-Family - For Sale	$441,284
	SF Attached/Townhome - Rental	$435,000
	Multi-Family - Rental	$272,000
Compact-Refill		
	SF Small Lot Detached	$853,800
	SF Large Lot Detached	$1,093,742
	SF Attached/Townhome - For Sale	$399,000
	Multi-Family - For Sale	$403,700
	SF Attached/Townhome - Rental	$406,000
	Multi-Family - Rental	$249,000
Urban		
	SF Small Lot Detached	$885,600
	SF Large Lot Detached	$1,134,476
	SF Attached/Townhome - For Sale	$377,200
	Multi-Family - For Sale	$397,900
	SF Attached/Townhome - Rental	$384,000
	Multi-Family - Rental	$245,000

Equation 5-4: Average Housing Value by Type

$$Hv_T = Havg_T * \left(\frac{Inc_{bg}}{Inc_{St}}\right)$$

Where:

$Hv_T = Houshold\ average\ value\ for\ housing\ type\ T\ adjusted\ for\ sub-regional\ income$

$Havg_T = Statewide\ houshold\ average\ value\ for\ housing\ type\ T$

$Inc_{bg} = \ Household\ average\ income\ for\ a\ given\ block\ group\ (at\ the\ grid\ scale)$

$Inc_{bg} = \ Statewide\ average\ income$

Step 2: Calculate monthly mortgage payment by housing value type. The calculation of monthly mortgage payments utilizes the adjusted housing value by type fields calculated in the previous step. The monthly mortgage payment is calculated for each housing type using Equation 5-5.

Equation 5-5: Monthly Mortgage Payment by Housing Type

$$Mp_T = Hv_T * (\frac{\frac{In_{rt}}{(12*100)}}{(1-\left(1+\left(\frac{In_{rt}}{(12*100)}\right)\right)^{(-1*Y*12))}})$$

Where:

$Mp_T = Monthly\ morgage\ payment\ for\ housing\ type\ T$

$Hv_T = Houshold\ average\ value\ for\ housing\ type\ T\ adjusted\ for\ sub-regional\ income$

$In_{rt} = Annual\ interest\ rate$

$Y = Years\ to\ term$

Step 3: Calculate annual income for each housing type for ownership and rental houses in transit proximate and market rate locations. The model assumes that a certain level of income is required in order to own houses of specific values and these values are influence by the location of homes and the type of home. The model assumes that transit proximate homes (within a quarter mile from a transit stop) will have higher values than those that are market rate (greater than a quarter mile to a transit location). For both of these proximity assumptions the model calculates ownership income and then calculates rental income. The equation for income for houses by type that are owned is shown in Equation 5-6. The equation for calculating rental house income is presented in Equation 5-7.

Equation 5-6: Ownership Housing, Required Income by Housing Type

$$IncO_T = (Hv_T * I_{rt}) + (Hv_T * Tax_{rt}) + (Hv_T * 12 * \left(\frac{1}{Inc_{pct}}\right))$$

Where:

$IncO_T = Annual\ income\ required\ to\ own\ housing\ type\ T$

$Hv_T = Houshold\ average\ value\ for\ housing\ type\ T\ adjusted\ for\ sub-regional\ income$

$I_{rt} = Annual\ insurance\ rate$

$Tax_{rt} = Annual\ tax\ rate$

$Inc_{pct} = Percent\ of\ annual\ income\ that\ is\ the\ morgage\ payment$

Equation 5-7: Rental Housing, Required Income by Housing Type

$$IncR_T = Hv_T * 12 * Rnt_{pct} * \left(\frac{1}{Inc_{pct}}\right)$$

Where:

$IncR_T = Annual\ income\ required\ to\ rent\ housing\ type\ T$

$Hv_T = Houshold\ average\ value\ for\ housing\ type\ T\ adjusted\ for\ sub - regional\ income$

$Rnt_{pct} = Annual\ rent\ as\ a\ percent\ of\ morgage\ payment$

$Inc_{pct} = Percent\ of\ annual\ income\ that\ is\ the\ morgage\ payment$

Step 4: Calculate number of households for each dwelling unit type by LDC, ownership/rental, and refill/greenfield. For each grid cell, the model calculates the number of households that fall into each LDC category, whether they are rental or ownership, and for compact households, whether they are refill or greenfield. The model utilizes the LDC and refill flags to classify household counts into the correct category. It then uses assumptions detailed in Table 5-2 to identify the percentage of each household type that are rented and owned.

Table 5-2: Percent Rental vs. Percent Ownership by Unit Type & LDC

LDC Type	*Unit Type*	*% For Sale Units*
Standard		
	SF Large Lot Detached	100%
	SF Small Lot Detached	100%
	Townhome	73%
	Multi-Family	19%
Compact-Greenfield LDC		
	SF Large Lot Detached	100%
	SF Small Lot Detached	100%
	Townhome	73%
	Multi-Family	19%
Compact-Refill LDC		
	SF Large Lot Detached	100%
	SF Small Lot Detached	100%
	Townhome	73%
	Multi-Family	19%
Urban LDC		
	SF Large Lot Detached	100%
	SF Small Lot Detached	100%
	Townhome	73%
	Multi-Family	19%

Step 5: Calculate the number of households within each income range by LDC, ownership/rental, and refill/greenfield. Having calculated the number households and incomes for each grid cell by LDC, ownership and rental, and refill and greenfield, the model then calculates the number of households that fall within each income range by LDC, ownership and rental, and refill and greenfield.

Step 6: Aggregate number of households by income ranges, LDC, ownership/rental, and refill/greenfield into household totals by income range. For each household count by income range calculated in the previous step, the model then totals all the household income ranges together. This combines the LDCs and rental/ownership households together producing total number of households for each income range.

Step 7: Merge new household income ranges with base year income ranges to produce the end state income scenario. The final process in the income model merges the new household income fields produced in the previous steps with the base year household income ranges from the loaded base table. For each field produced in the previous steps, the end state scenario value for each grid cell is calculated using Equation 5-8.

Equation 5-8: End state Household Income Calculation

$$HH_{incS} = HH_{incN} + HH_{incD} - HH_{incB}$$

Where:

$HH_{incS} = End\ state\ household\ income\ field$

$HH_{incN} = New\ household\ income\ field\ values$

$HH_{incD} = Developable\ lands\ houshold\ income\ field\ values$

$HH_{incB} = Base\ year\ household\ income\ field\ values$

Demographics Engines Output Table

The table produced by the demographics engine contains a suite of income fields, which act as primary inputs to the UrbanFootprint Travel Model and the Public Health Model. It is a full coverage, end state table and contains the same geography as the scenario core outputs and the base year table.

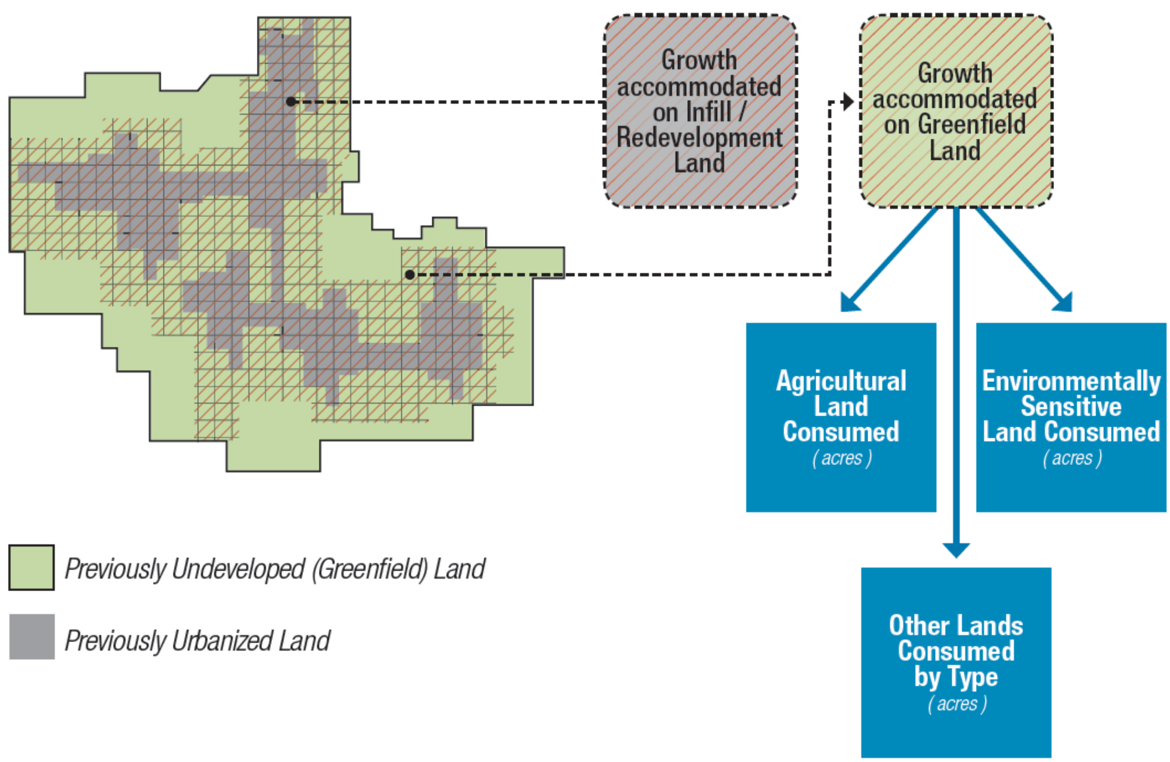
UrbanFootprint Metrics Modeling

CHAPTER 6
Land Consumption

As a spatial model, UrbanFootprint produces fine-grained assessments of how land is developed or consumed in a future scenario. In the context of the model, “land consumption” refers to the measurement of land area needed to accommodate new growth. This includes ‘greenfield’ development on previously undeveloped land, and refill (infill and redevelopment) growth in existing urban areas.

Land consumption calculations for future scenarios are built upon an assessment of the base (existing) environment. The base data loading process assigns to each grid cell descriptors of its land type conditions, which are used to describe how new growth impacts the landscape; whether it will consume new land as greenfield development, intensify or modify existing urban areas as refill development, or be excluded from development by environmental, conservation, or policy constraints. For a future scenario, UrbanFootprint analyzes the extent of land use change and maps the area of greenfield land as well as areas of previously urbanized land (refill development) required to accommodate new residential and employment growth (see Figure 6-1).

Figure 6-1: The Land Consumption Measurement Process



Land Consumption Inputs

The Land Consumption analysis accounts for consumed land by intersecting scenario ‘change areas’ with an assessment of land cover in the base environment. The assessment of land cover in the base environment can be as detailed or as general as the user and data allows. UrbanFootprint can analyze growth impacts on a variety of specific land types (i.e. specific types of agricultural lands, forest or range lands, or other lands of specific interest), provided that the existing environment is described in adequate detail. For UrbanFootprint version 1.0, the land consumption module defines land types via a land type reference dataset compiled from data derived from the California Farmland Mapping and Monitoring Program (FMMP) and California Protected Areas Database (CPAD) datasets. The land type reference dataset provides a base year assessment of urban, greenfield, and constrained lands, from which land consumption can be calculated.

Land Consumption Methodology

In UrbanFootprint version 1.0, land consumption is defined as the conversion of base year greenfield (undeveloped) land to urban uses. In order for newly-urban change areas to be counted as land consumed, they must have a residential density greater than 0.5 dwelling unit per acre, and/or an employment density of greater than 1 employee per acre.

The general process for calculating land consumption in UrbanFootprint version 1.0 is detailed in the following steps:

Step 1: Join the land type dataset to the net increment table. The land type grid is joined to the net increment table on their primary keys.

Step 2. Quantify greenfield land consumption using change area definition. To identify where in a new scenario land consumption occurs, change grid cells are identified through a filtering process. Change grid cells are identified by whether they are allocated growth via a place type *and* have greater than 0.5 dwelling units per acre or greater than 1 employee per acre. To identify grid cells that include greenfield land consumption, change grid cells are further filtered by whether their developable greenfield acreage is greater than their urban acreage. If there is more developable greenfield acreage than urban, a grid cell is considered greenfield. Otherwise, it is flagged as containing refill growth. Greenfield land consumption is then calculated by summing greenfield grid cells in a scenario, as described in Equation 6-1.

Equation 6-1: Greenfield land consumption acreage

$If\ place\ type = \boldsymbol{True}\ and\ greenfield\ developable\ acres > urban\ developable\ acres;$

$If\ net\ dwelling\ units > 0.5\ or\ net\ employees > 1:$

$$Lc_g = \sum d_{pct} * Ac_d$$

Where:

$Lc_g = Acres\ of\ greenfield\ land\ consumed$

$d_{pct} = development\ percentage\ of\ given\ grid\ cell\ (percent\ of\ grid\ developing)$

$Ac_d = Acres\ of\ developable\ land\ in\ a\ grid\ cell$

Step 3. Quantify refill land consumption using refill assumptions. The calculation of refill acreage follows the same logic as that for greenfield consumption, but uses the inverse Boolean flag to identify a parcel as refill, as described in Equation 6-2.

Equation 6-2: Refill development acreage

$If\ place\ type = \boldsymbol{True}\ and\ greenfield\ developable\ acres < \ urban\ developable\ acres;$

$\quad If\ net\ dwelling\ units > 0.5\ or\ net\ employees > 1:$

$$Lc_r = \sum d_{pct} * Ac_d$$

Where:

$Lc_g = Acres\ of\ refill\ development$

$d_{pct} = development\ percentage\ of\ given\ grid\ cell\ (percent\ of\ grid\ developing)$

$Ac_d = Acres\ of\ developable\ land\ in\ a\ grid\ cell$

Land Consumption Output Table

The land consumption module for UrbanFootprint version 1.0 produces regional greenfield and refill land consumption acreages and a table containing grid-scale refill and greenfield acres which can be visualized for reporting purposes. Additional detail in the analysis of refill and greenfield land consumption can be added with the inclusion of more detailed base year land type data.

CHAPTER 7
Transportation Model Overview

UrbanFootprint incorporates a comprehensive ”sketch” travel model that interacts with regional travel network data to produce vehicle miles traveled (VMT), mode choice, and congestion estimates for land use + transportation scenarios, as well as transportation-related costs, greenhouse gas (GHG) emissions, and pollutant emissions. The core of UrbanFootprint’s travel engine was adapted from the MXD model (described below) created by Fehr & Peers, an internationally-known firm specializing in state of the art travel behavior research and prediction.

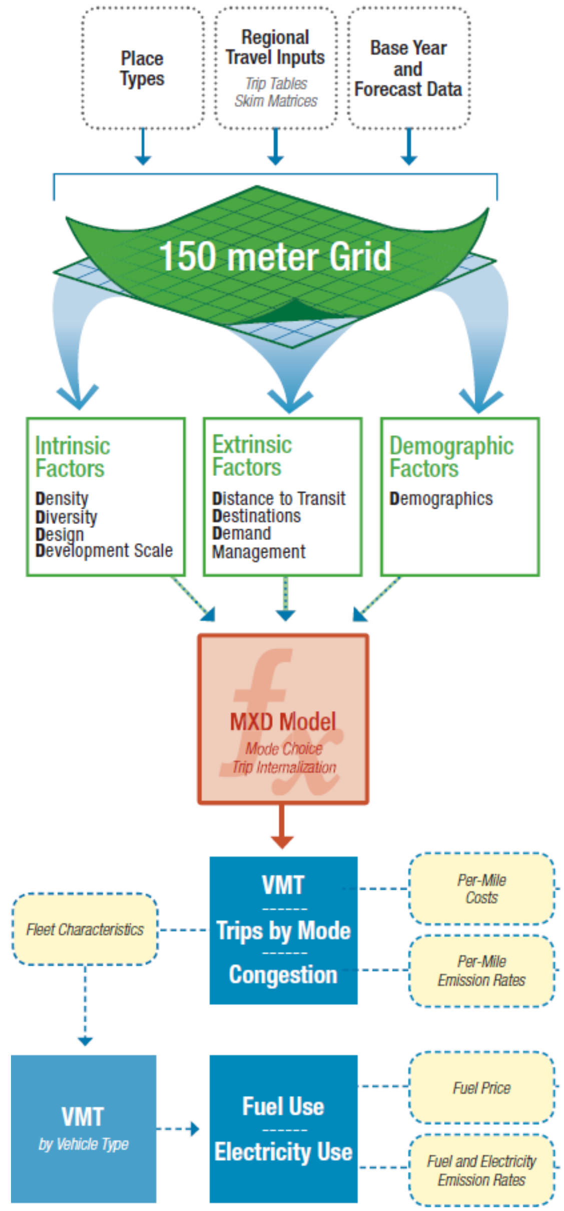


Figure 7-1: Overview of the UrbanFootprint travel engine

The MXD method allows differentiation among a broad array of land use Place Types, the building blocks of UrbanFootprint, calculating the vehicle trip reductions resulting from the specific combination of D variables that characterize each Place Type. MXD transportation-demand relationships allow the combination of intrinsic D variables for a specific Place Type, coupled with the extrinsic factors that describe the place’s location within the region, to dictate the degree to which the place generates more or less vehicle travel than the regional average.

Costs and emissions estimates for each scenario are based on policy inputs, which allow the user to see the quantification of the effects of variations in factors including: fuel price; the carbon content of fuels; vehicle fuel economy; vehicle fleet turnover; and the relationship between a widespread shift to vehicle electrification and the carbon intensity of the electricity generation portfolio. UrbanFootprint thus allows users to quickly and easily see the transportation-related impacts of the changes in transportation systems, urban form and regional development patterns between various land use and transportation scenarios.

Travel Forecasting in UrbanFootprint

The travel forecasting capabilities within UrbanFootprint are based on a comprehensive body of research on the relationships between travel generation and the characteristics of the built environment. The supporting research includes:

- *Travel and the Built Environment*; Ewing and Cervero; 2010
- *Traffic Generated by Mixed-Use Developments—Six-Region Study;* Ewing and Walters, et al; 2011. (Included as Appendix B of this report.)
- *2010 California Regional Transportation Plan Guidelines*, California Transportation Commission
- *Assessment of Local Models and Tools for Analyzing Smart-Growth Strategies;* Caltrans , DKS; 2007
- *Growing Cooler – The Evidence on Urban Development and Climate Change;* Ewing and Walters; et.al.; 2008
- *Guidelines for Quantifying the GHG Effects of Transportation Mitigation*, California Air Pollution Control Officers Association, 2010

This and other research have found that urban form, transportation supply and management policies affect vehicle miles travelled (VMT), automobile and transit travel through at least eight mechanisms, referred to as the "8Ds".

Measurement of the '8Ds' in UrbanFootprint

The UrbanFootprint travel engine uses the findings from California and nationwide MXD research to quantify the transportation effects of differences in transportation and development form ranging from highly-sustainable compact, mixed and transit-oriented forms to land use patterns that are more auto-dependent. This relies upon measurement of each of the following '8Ds' for each micro-scale development area (each 5.5-acre land use grid cell).

1. **Density** – Dwellings and jobs per acre of development.
2. **Diversity** – Mix of housing, jobs and retail, measured in terms of ratios such as jobs/housing, retail/housing and jobs mix (closeness to a balance among uses).
3. **Design** – Connectivity and walkability, measured in terms of how fine-grained the circulation networks through metrics of network density, such as walkable street intersections per square mile
4. **Destinations** – Regional accessibility to activities from the regional travel model networks "skim matrices" of travel distances and travel times among all development areas or travel analysis zones (TAZs).
5. **Distance to Transit** – Proximity to fixed-guideway service measured from the UrbanFootprint development grid cell to the nearest transit stops, and expressed in terms of transit stops within walking radii of ¼ and ½ mile.
6. **Development Scale** – Absolute local amounts of population and jobs within the development grid cell's neighborhood (critical mass and magnitude of compatible uses), measured in terms of a ½ mile walking radius

7. **Demographics** – Household size, income and auto ownership of the residential development types contained in the grid cell.
8. **Demand Management** – Automobile travel disincentives, including regional pricing of auto travel through fuel costs, mileage-based fees and taxes and parking charges (Method has been developed, but is not implemented in UrbanFootprint version 1.0).

UrbanFootprint quantifies the relationships to the first seven "Ds" through a series of equations from the most recent and rigorous statistical study: *Traffic Generated by Mixed-Use Developments—Six-Region Study Using Consistent Built Environmental Measures*, prepared for the US EPA and reviewed by the American Society of Civil Engineers. The study developed hierarchical models that capture the relationships between the "D" factors and the amount of travel generated by over 230 mixed-use developments of a wide variety of settings and sizes across the US, including the Sacramento and San Diego regions. The predictive accuracy of the methods were validated through field surveys of traffic at almost 30 other development sites, more than half of which are located in California, at locations in San Diego, Orange County , Sacramento and the San Francisco Bay Area.

The resulting method, known as the MXD method, uses a series of equations to estimate the likely degree to which a development area's external traffic generation will be reduced due to development density, diversity, design, destination accessibility, distance to transit, demographics and development scale. UrbanFootprint uses the MXD method and other California research on the effects of various Demand Management strategies as its '8D' travel engine.

UrbanFootprint combines the MXD estimates of trip generation by travel mode with regional information on transportation networks and travel distances among activities to compute measures of accessibility and vehicle miles travelled (VMT). For consistency with regional transportation policy and programs, UrbanFootprint draws this network information from each MPO's regional travel models, reflecting the region's Sustainable Communities Strategy (SCS) and modal emphasis alternatives from its Regional Transportation Plan (RTP). Derivation of MXD Method

The research foundation and analysis approach of the MXD method addresses a range of development characteristics by examining travel generation for a broad spectrum of development sites of varying sizes, mixes and locations, and layouts. The underlying national research, sponsored by the US EPA:

- Pooled travel and land use data from 239 mixed-use developments within six diverse regions across the US: Sacramento, Portland, Seattle, Houston, Atlanta and Boston.
- Analyzed travel as a multi-level phenomenon to account for differences in relationships produced by the differences among the regions, the MXD characteristics, and the characteristics of the travelers themselves.
- Related survey-reported travel destinations and mode choices to site characteristics including: size, mix of uses, urban design features, context and regional location and accessibility.
- Determined the likelihood of internal capture as a nested travel outcome measure as well as the likelihood of walking and transit use on external trips and the length of external auto trips.

- Validated the resulting models by comparison to traffic generation counts at mixed use sites in various parts of the U.S.

The EPA MXD research used standard protocols to identify and generate datasets for 35,877 trips to/from/within 239 MXDs in six large and diverse metropolitan regions. Data from household travel surveys and GIS databases were pooled for these MXDs, and travel and land use variables were consistently defined across regions.

To identify MXDs in the six study regions, city and county planners were interviewed and asked to identify sites meeting the above definition within their jurisdictions. In two of the six regions, local traffic engineers were asked to review the selected sites to confirm that the chosen sites met the criteria normally applied by practitioners to identify mixed-use development.

The number of study MXDs ranged from 24 in Atlanta to 59 in Boston.

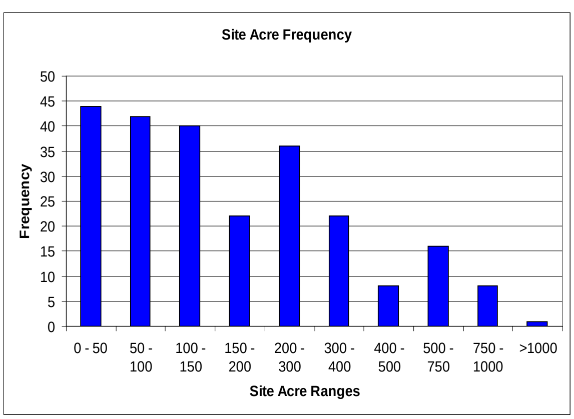
Table 7-1: Study MXDs

Region	MXDs
Atlanta	24
Boston	59
Houston	34
Portland	53
Sacramento	25
Seattle	44
Total	239

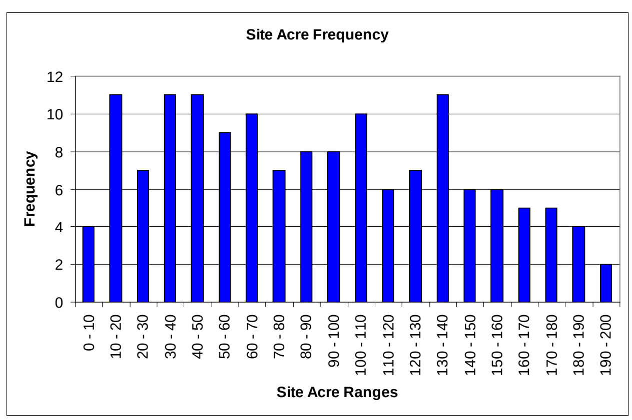
The 239 survey sites vary in size, population and employment densities, mix of jobs, housing and retail, presence or absence of transit and location within the region, as shown in the following figures.

Figure 7-2: MXD Site Size Distribution

All 239 Sites



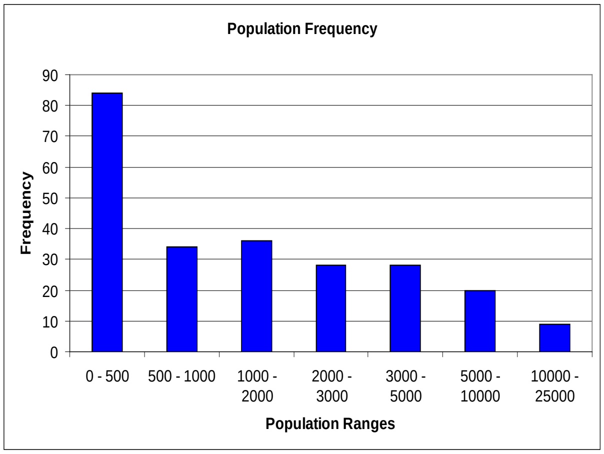
Sites Smaller than 200 Acres



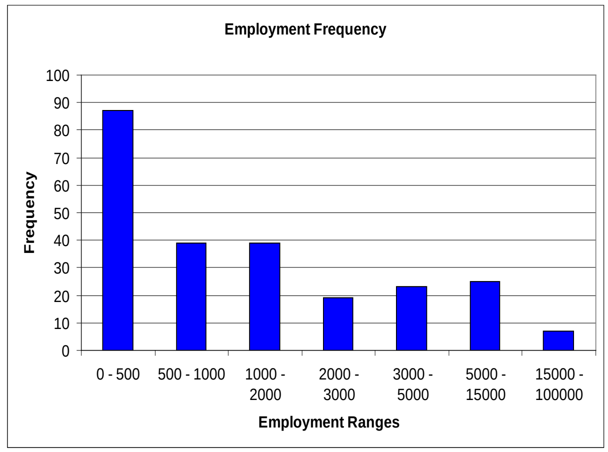
Site sizes range from under ten acres to over 1000 acres, with about 150 of the sites at or below 200 acres.

Figure 7-3: MXD Site Population and Employment Distributions

Distribution of 239 MXD Population



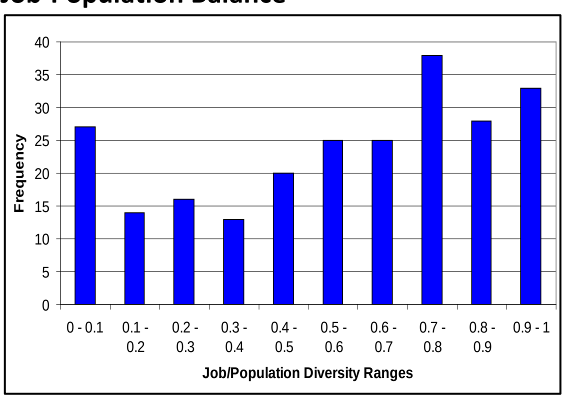
Distribution of 239 MXD Employment



The majority of sites had either less than 2000 population or less than 2000 employees, but at least 20 sites had over 10,000 population and/or over 10,000 employees, representing a category of development equivalent to large specific plans of master planned communities.

Figure 7-4: MXD Site Job-Population Balance Distribution

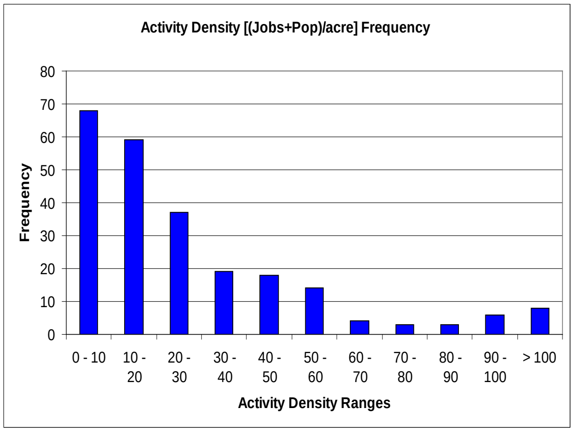
Job-Population Balance



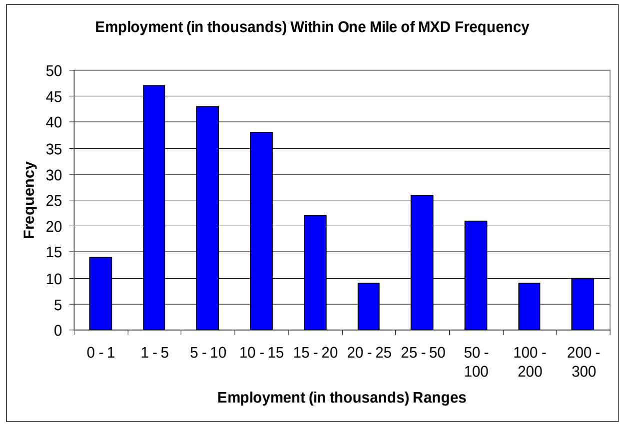
In the above graph, an index of 1.0 indicates that the MXD has one job for every five residents, a ratio found to best predict internal capture of trips within MXDs. In the job-population graph, an index of 0.0 indicates all jobs or all housing.

Figure 7-5: Density and Context of MXD Sites

Development Density



Amount of Nearby Employment



The majority of survey sites have low-to-moderate development densities with less than 30 residents and jobs per acre, translating to less than ten dwelling units per acre and/or floor-area ratios of less than 0.25. However, about 20 of the sites have densities of 80 or more residents and jobs per acre, representing about 30 residential units per acre and/or FAR approaching 0.75. The sites also are located in a full range of contexts, many with fewer than 5000 jobs within a mile of the site, but with almost 20 sites with over 100,000 jobs within a mile of the MXD.

Research Method

The MXD research applied hierarchical or multi-level modeling to account for dependence among observations, in this case the dependence of trips to, from, and within a given MXD. All the trips to/from a given MXD share the characteristics of the MXD, that is, are dependent on these characteristics. This dependence violates the independence assumption of ordinary least squares regression. Hierarchical (multi-level) modeling overcomes these limitations, accounting for the dependence among observations and producing more accurate coefficient and standard error estimates.

The model structure had three levels: trip/traveler/household at Level 1; MXD at Level 2; and region at Level 3. Within a hierarchical model, each level in the data structure is formally represented by its own sub-model. The sub-models are statistically linked. Hierarchical nonlinear models were estimated for the dichotomous outcomes (internal vs. external, walk vs. other, and transit vs. other). Hierarchical linear models were estimated for the continuous outcome (auto travel distance).

Research Results

Of the 35,877 trip ends generated by the EPA study MXDs, a total of 29% of the total trip ends were either internal, walk or transit, and would be deducted from a trip generation estimate based on rates derived from isolated single-use, stand-alone sites. However, the 29% figure masks considerable variance both in the contributions to trip reduction of internal capture, walking, and transit use, and the overall percentage reduction from site to site. Good models may help to explain the unexplained variance in these percentages.

Using the data and models described above, the MXD study established quantifiable relationships between a development site's external traffic generation and the "D" factors. In the case of home-based work trips, the odds of an internal trip decline with household size and vehicle ownership per capita, and increase with a MXD's job-population balance. Internal capture is thus related to two D variables, *diversity* and *demographics*. Larger households have more complex activity patterns, which are more likely to take them beyond the bounds of an MXD. Households with higher vehicle ownership have fewer constraints on the use of household vehicles for long trips. A high job-population balance value translates into more opportunities to live and work on site.

Development Characteristics Found to have Statistically Significant Effect on Traffic Generation
Density **Employment within the site** **Activity density (population plus employment) within the site**
Diversity **Index of the relative balance of jobs and housing within the site** **Amount of employment within 1 mile of the site**
Design **Density of intersections within the site as a measure of street connectivity and block size**
Distance from Transit **Proportion of site with bus stop within ¼ mile** **Presence of a rail station within the site**
Destination Accessibility **Proportion of regional employment within 30 minutes by transit** **Proportion of regional employment within 20 or 30 minutes by car**
Development Scale **Gross acreage of the development**
Demographics **Number of household members** **Household auto ownership per capita**

For home-based other trips, the odds of internal capture decline with household size and vehicle ownership per capita and increase with a MXD's land area, job-population balance, and intersection density. Internal capture for trips from home to non-work destinations is thus related to *development scale*, *diversity*, *design*, and *demographics*. Relationships to household size and vehicle ownership are as explained above. As for the other significant variables, jobs-housing balance spawns on-site travel since jobs include those in the retail sector, suggesting the presence of shops and restaurants encourages some residents to substitute walk trips for out-of-neighborhood car trips. Also, a large land area increases the likelihood that non-work destinations will be on-site while high intersection density increases routing options, makes routes more direct, creates frequent street crossing opportunities, and makes trips seem more eventful. Among the built environment variables analyzed, the most statistically significant predictor of internal capture for home-based other trips is job-population balance followed by an MXD's land area and then by its intersection density.

For non-home-based trips, the odds of internal capture decline with household size and vehicle ownership, and increase with land area, employment, and intersection density of the MXD. Internal capture is thus related to *design*, *development scale*, and *demographics*. Relationships to land area and intersection density are explained above. The relationship to employment is likely due to the greater likelihood of matching employee's desired trips to on-site destinations when there are more attractions nearby. The most statistically significant relationship is to intersection density, followed by land area, and then by employment.

Walking between the MXD and off-site locations is related to MXD *diversity*, *destination accessibility*, and *demographics*. For all trip purposes, the odds of external walking decline with household size and vehicle ownership per capita. For commute and other home-based travel, external walking also increases with job-population balance within the MXD and number of jobs outside the MXD within a mile of the boundaries. Reasons for the positive association between internal job-population balance and walking for external work trips may be that on-site balance creates opportunities for trip chaining and/or that on-site balance is associated with off-site, nearby balance as well, thus further inducing walk trips. For external home-based other and non-home based trips, walking on external trips is related to measures of *development scale*, *density*, *diversity*, *design*, *destination accessibility*, as well as *demographics*. The larger the area of the MXD, the longer the external trips and the less likely they will be made by walking. The higher the activity density, the better the pedestrian environment and the more accessible attractions will be to those traveling into the community. For external non-home-based trips, the odds of walking increase with the intersection density of the MXD, as well as the activity density of the MXD and the number of jobs immediately outside the MXD. High intersection density within the MXD makes walking to/from activities outside the MXD that much more direct.

The odds of transit use on external trips are related to measures of *density, design*, *destination accessibility*, *distance to transit*, and *demographics*. The odds of transit use are significantly higher for households living within ¼ mile of a bus stop than those farther away. Having a rail stop within or adjoining the MXD also has a positive correlation for all trip purposes. Transit use declines with household size and vehicle ownership per capita, and increases with the intersection density of the MXD and the number of jobs within a 30-minute trip by transit. A higher intersection density translates into a more direct walk trips to and from transit stops, and also possibly more efficient routing of transit vehicles. More jobs within 30 minutes by transit increases the likelihood a particular job being within easy travel distance for residents.

The study also found that the length of travel for vehicle trips entering and leaving the MXD related to a number of D variables. Vehicle miles traveled (VMT), an important factor in impacts ranging for need for roadway capacity expansion to energy use and generation of emissions and GHG, thus relates to all of the variables discussed above in connection with internal trip capture and mode choice as well as some additional variables. For external home-based work trips by private vehicle, trip distance increases with household size, vehicle ownership per capita, and land area of the MXD, and declines with a project's job-population balance and the share of regional jobs reachable within 30 minutes by automobile. Trip distance is thus related to four types of D variables, *development scale*, *diversity*, *destination accessibility*, and *demographics*. Larger MXDs produce and attract longer external trips simply because the shortest trips are internalized. MXDs with good job-population balance apparently reduce the need for very long external trips – e.g., on-site residents patronize on-site retail outlets. They may also facilitate trip chaining. MXDs with good auto accessibility to regional jobs generate shorter trips because more trip attractions are nearby. On the other hand, larger households have more complex activity patterns, which lengthen trips. More vehicles per household frees up family cars for trips to more distant destinations.

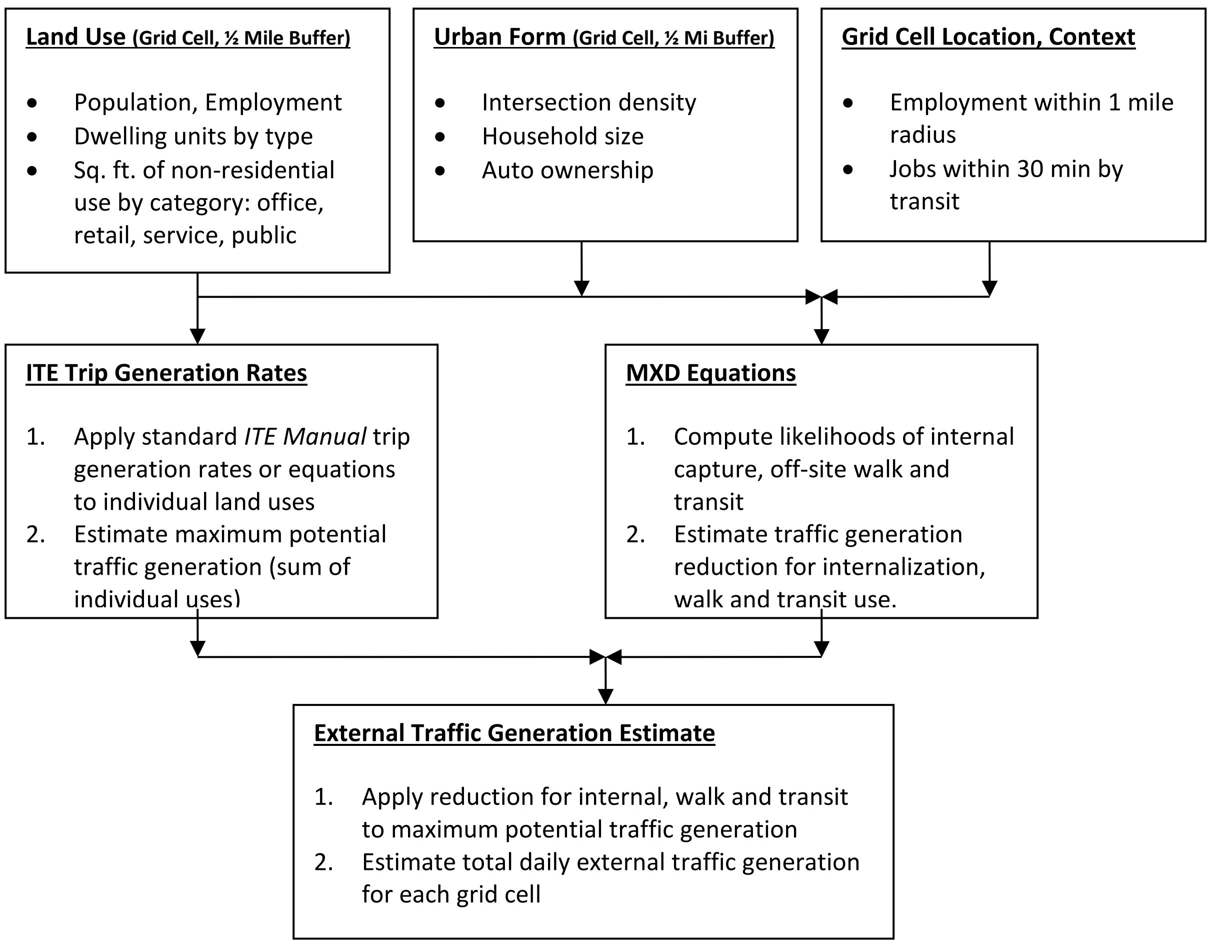
For external home-based other trips, trip distance increases with household size and vehicle ownership per capita, and declines with the job-population balance within the MXD and the share of regional jobs reachable within 20 minutes by automobile. Internal capture is thus related to measures of *diversity*, *destination accessibility*, and *demographics*. Relationships to job-population balance, accessibility to regional employment, household size, and vehicle ownership follow the same explanations provided above. Note that the destination accessibility measure with the greatest explanatory power is the number of jobs reachable within *20 minutes* by automobile, not *30 minutes* as with home-based work trips. This makes sense since home-based other trips are shorter than home-based work trips.

For external non-home-based trips, trip distance increases with household size and vehicle ownership per capita, and declines with the job-population balance within the MXD, intersection density within the MXD, and the share of regional jobs reachable within 20 minutes by automobile. External trip length is thus related to measures of *diversity*, *design*, *destination accessibility*, and *demographics*. As for the one new variable (*design*), higher intersection density within an MXD (and perhaps its surroundings as well) makes for more direct connections to external trip attractions.

MXD Methodological Steps

The EPA MXD procedure involves first calculating the traffic generation for the individual land uses within the site, using standard trip rates or equations from the Institute of Transportation Engineers (ITE) *Trip Generation* informational report. For certain land use types (residential, shopping center, office), *Trip Generation* provides non-linear equations indicating that trip rates decline as the site size increases, reflecting some degree of internalization even within sites with a single or dominant land use type. For these three land use categories (ITE codes 210, 710 and 820) and any other categories with non-linear trip generation equations, the MXD method uses the trip generation equation, as prescribed in and defined in ITE *Trip Generation,* Volume 1. For all other land use categories, the MXD method uses the trip rate, or linear equation from the report to compute the potential traffic generation for individual uses. The MXD method next reduces the total potential traffic generation of the individual uses from the report to account for trips captured internal to the site, and then reduces the remaining trips that leave the site to account for walking or transit rather than automobile due to the site's size, mix, context, and transit options. The process is illustrated in the following.

Figure 7-6: Calculating External Traffic Generation for Mixed-Use Development



The MXD method uses a series of equations to estimate the likely degree to which a development area's external traffic generation will be reduced due to: a) trip internalization, b) walking, or c) transit use for off-site travel. Equations for computing the trip reduction likelihoods have the following form:

$$\text{Log Odds of (Internal Capture, Walk, Transit)} = \text{Constant} + \sum [\text{Ln(VAR)*Coeff}]$$

Where Ln indicates that the natural logarithm is taken of each built environment "D" variable (VAR), and the result is multiplied by a variable-specific coefficient (Coeff). The results of the individual calculation for each variable are summed and added to the Constant to produce the logarithmic odds of travel being, respectively, either internalized, pedestrian or transit. The variables used in the MXD equations are listed below.

Outcome Variables

- INTERNAL –Trip remains within the MXD (1=internal, 0=external)
- WALK –Travel mode on an external trip is walking (1=walk mode, 0=other)[i]
- TRANSIT - Travel mode on an external trip is bus or rail (1=transit, 0=other)

Explanatory Variables

- AREA – Gross land area within the MXD
- EMP – Employment within the MXD
- ACTDEN – Resident population plus employment per square mile of gross land area within the MXD
- JOBPOP – Jobs/ housing balance (index comparing the MXD ratio to the "ideal" regional average)
- RETPOP - Balance of retail employment/ population (index comparing the MXD ratio to the "ideal" regional average)
- INTDEN - Number of intersections per square mile of gross land area within the MXD or within 1 mile of the MXD
- EMPMILE – Total employment within 1 mile of the MXD
- EMP30T– Total employment within 30-minutes by transit from MXD
- HHSIZE – Number of members of the household
- VEHCAP – Number of motorized vehicles per person in the household

The list contains a full array of "D" variables often associated with development characteristics that affect vehicle trip generation, including development density, diversity, design, destination accessibility, distance from transit, development scale and demographics. The hierarchical modeling tested the individual and combined effects of the seven types of D variables on the travel characteristics of the 239 MXDs.

The following tables present the discovered relationships, applied in the form: Ln Odds of Internal Capture, Walk, Transit = Constant + ∑ Coeff * Ln (VAR). The constant term, variables (VAR) and coefficients (Coeff) are presented in the following tables.

Table 7-2: Log Odds of Internal Capture (log-log form)

	Home-Based Work			Home-Based Other			Non-Home Based		
	Coeff	**t-ratio**	**p-value**	**Coeff**	**t-ratio**	**p-value**	**Coeff**	**t-ratio**	**p-value**
Constant	-1.75			-2.43			-5.72		
EMP	–	–	–	–	–	–	0.208	3.28	**0.002**
AREA	–	–	–	0.486	3.61	0.001	0.468	4.58	**<0.001**

JOBPOP	0.389	2.62	0.010	0.399	4.55	<0.001	–	–	**–**
INTDEN	–	–	–	0.385	1.92	0.055	0.638	4.95	**<0.001**
HHSIZE	-1.33	-6.03	<0.001	-0.867	-13.0	<0.001	-0.237	-4.54	**<0.001**
VEHCAP	-0.990	-4.15	<0.001	-0.590	-8.19	<0.001	-0.163	-3.00	**0.003**
pseudo-R^2		**0.01**			**0.20**			**0.30**	

Table 7-3: Log Odds of Walking on External Trips (log-log form)

	Home-Based Work			**Home-Based Other**			**Non-Home Based**		
	Coeff	**t-ratio**	**p-value**	**Coeff**	**t-ratio**	**p-value**	**Coeff**	**t-ratio**	**p-value**
Constant	-5.55			-10.96			-15.09		
AREA				-0.415	-4.27	<0.001			
ACTDEN				0.370	2.74	0.007	0.377	3.12	**0.003**
JOBPOP	0.226	2.46	0.015	0.219	3.83	<0.001			
INTDEN							0.803	5.05	**<0.001**
EMPMILE	0.385	3.12	0.002	0.450	5.05	<0.001	0.440	5.09	**<0.001**
HHSIZE	-1.57	-6.29	<0.001	-0.486	-5.05	<0.001	-0.281	-2.59	**0.010**
VEHCAP	-1.84	-7.00	<0.001	-0.768	-7.62	<0.001	-0.242	-2.13	**0.033**
pseudo-R^2		**0.19**			**0.51**			**0.64**	

Table 7-4: Log Odds of Using Transit on External Trips (log-log form)

	Home-Based Work			Home-Based Other			Non-Home Based		
	Coeff	t-ratio	p-value	Coeff	t-ratio	p-value	Coeff	t-ratio	**p-value**
Constant	-8.05			-6.08			-2.69		
ACTDEN				0.324	2.89	0.005			
INTDEN	1.12	4.44	<0.001						
EMP30T	0.209	2.98	0.004				0.134	3.29	**0.002**
HHSIZE	-1.14	-6.31	<0.001	-0.958	-8.48	<0.001			
VEHCAP	-1.68	-8.56	<0.001	-1.09	-8.91	<0.001	-0.340	-3.74	**<0.001**
BUSSTOP	0.357	2.08	0.037	0.467	4.04	<0.001			
pseudo-R^2	**0.47**			**NA**			**NA**		

For internal capture, the dependent variable is the natural log of the odds of an individual making a trip with both ends within an MXD. Depending on the trip-purpose, this probability is related to the development scale, a variety of land use mix variables, a variable measuring the urban design quality of the MXD, and several demographic variables. The log odds probability of walking to external destinations is related to the MXD's size, density, development mix, urban design, demographics and the number of jobs within a mile of the site. The propensity to use transit is a function of demographics and the amount of transit service available to the site in terms of the site's transit accessibility to the rest of the region, expressed in terms of jobs within 30 minutes by transit.

MXD Method Validation

Validation of the MXD method was accomplished by applying the models to 27 MXDs for which external traffic counts were available. The validation sites include the three explicitly studied for NCHRP Report 684, and the sites used as the basis for the ITE *Trip Generation Handbook,* as well as eighteen conducted by Fehr & Peers, transportation consultants, for the EPA study and related work.

Six of the 27 validation sites are located in Florida, and three are located in Atlanta and Texas. Three of the nine are nationally known examples of smart growth or transit-oriented development: Celebration

Florida, Atlantic Station, and Mockingbird Station. Six sites are located in San Diego County and were designated by local planners and traffic engineers in 2009 as representing a wide range of examples of smart growth trip generators in that region. The twelve remaining sites are MXD development projects located elsewhere in California and in Utah, ranging from TOD sites (commuter rail and ferry) to conventional suburban freeway-oriented mixed use sites.

The validation sites were successful examples of mixed-use development. At the time each site was surveyed, it exhibited moderate to high levels of activity in terms of business sales, occupied residential units, property value and household income, with average or above-average person trips.

The sites represent a wide range of densities, land use mixes, and development scales. Populations of the validation MXDs range from none at all to nearly seventeen thousand, and employment levels range from near-zero to more than five thousand. Some sites are well served by transit, including three built around rail stations, while others are suburban and poorly served by transit. The diverse characteristics of the validation sample, provides a relatively thorough test of the method's responsiveness to the broad variety of mixed use development types.

The probabilities estimated with the MXD models and the resulting predicted external vehicle traffic counts demonstrate that the models are capable of predicting a wide range of internal capture rates and mode shares for external trips, taking into account development scale, site design, and regional context.

The statistical comparisons are shown in the following graph and table. The graph shows a strong association between daily external vehicle traffic predicted by the MXD model and the actual number of vehicles observed in the external vehicle counts. Of the Table statistics, the "Percent Root Mean Squared Error (%RMSE)", used in the transportation field to evaluate model accuracy, penalizes proportionally more for large errors and normalizes the error across different values of the quantity one is trying predict. A %RMSE of less than 40% is generally considered good. The MXD models improve the %RMSE compared to the ITE methods. The MXD models improve the %RMSE from 27%, produced by the best of the previously available trip generation estimation methods, to a figure of 17%. "R-squared" is a measure of the percentage of the variation in trip generation among the sites that is explained by the MXD model. Its computation is based on the squared difference between the observed and predicted external vehicle counts as a percentage of the squared variation of the observed external vehicle counts about the mean over the sites. The MXD models improve the R^2 to 0.96, markedly better than the 0.89 produced by the best of the previously published ITE methods, and indicating that the EPA method accounts for 96% of the difference in traffic generation among the 27 survey sites.

Table 7-5: Statistical comparison of models

	ITE	MXD
Average Model Error	16%	2%
% RMSE	27%	17%
R Squared	0.89	0.96

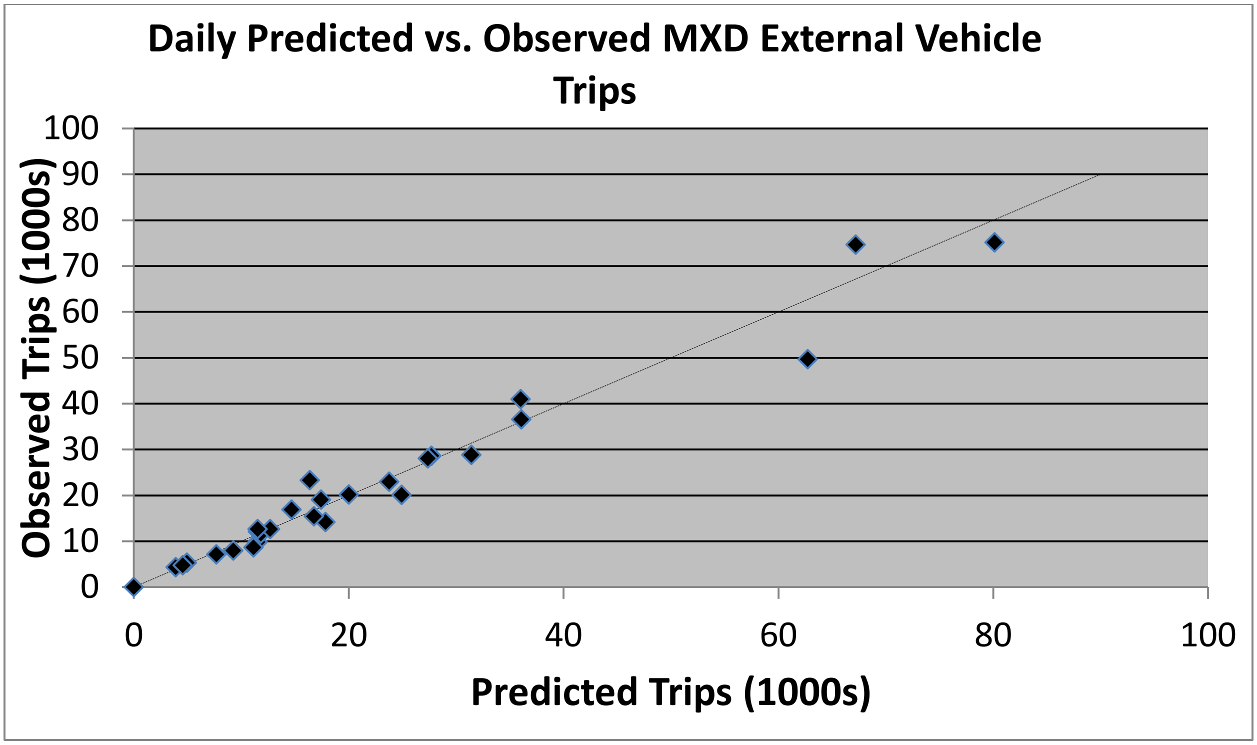


Figure 7-7: Daily predicted vs. observed MXD external vehicle trips

The validation test results indicate that the external traffic generation of an MXD is quantifiably related to the following development characteristics:

- The size of the site and its total employment
- The jobs / housing balance within the site
- The balance between housing and supporting retail within the site
- The density of development on the site
- The size of households and their auto ownership characteristics
- The amount of employment within walking distance of the site
- The pedestrian-friendliness of the site (small blocks and sidewalks)
- The level of transit service, measured as the employment within a 30 minute transit ride of the site

In sum, the equations that estimate MXD internal capture and walking and transit use produce trip generation reductions to the ITE *Trip Generation* informational report that are more accurate than those obtained from previously published methods including the ITE *Trip Generation Handbook*, and they meet or exceed performance criteria used in most areas of transportation planning and forecasting.

What is more, on average, the EPA MXD method eliminates any overestimation of traffic generation by mixed use developments. Considering the individual land uses contained within the 27 validation sites, the traffic estimation methods most commonly used in traffic impact studies, based on the methods contained in the *ITE Handbook*, predicts 16% more traffic than the counts. The EPA method remains slightly conservative but significantly reduces the overestimate, decreasing to 2% the average percentage by with the estimate of traffic generation exceeds the actual amount of traffic counted.

MXD Method Acceptance

In addition to the US EPA, which sponsored the MXD research, the method has been reviewed and accepted by other national, state, regional and local organizations. The research was peer reviewed and published by the American Society of Civil Engineers (ASCE) and published in the ASCE *Journal of Urban Planning and Development*.

SANDAG subjected MXD to thorough review by local transportation engineering professionals in San Diego cities and county and testing with data from SANDAG's travel survey and models. The SANDAG Board has adopted MXD for use in traffic impact evaluations and other transportation studies. MXD has also been used successfully in CEQA documents in Los Angeles and the San Francisco Bay Area.

Outside of California, it has been reviewed and accepted by the Virginia Department of Transportation, and local agencies for environmental impact assessments in Washington State and Utah.

Integration of MXD with CAPCOA and MPO Transportation Network Metrics

UrbanFootprint uses travel model run skims from regional MPOs as an input to its travel engine, which produces travel metrics at the local level (grid cells) for scenarios where change is described using Place Types. Using research conducted for the California Air Pollution Control Officers Association (CAPCOA), however, UrbanFootprint is also able to quantify the results of demand management at the regional level.

Within UrbanFootprint, each Place Type is described in terms of the eight demand-side "D" variables, based on the combination of the intrinsic characteristics of each Place Type and the location of the place within the regional context. Each geographic grid cell or place location is described in terms of its spatial relationship to all other locations within the study area, expressed in terms of travel time and cost by auto, transit and non-motorized modes. As a result, each land area described by a given Place Type and grid-cell location has vehicle trip, transit and non-motorized trips and VMT associated with the Place Types' density, diversity, design, destination accessibility, distance to transit, development scale, demographics and demand management attributes.

In addition to data contained within the Place Type and grid cell description of each region, UrbanFootprint exchanges, with each region's official travel demand model, data on transportation network characteristics, regional accessibility, and travel distances and times among regional activities. These data, obtained from each Metropolitan Planning Organization's (MPO) transportation model, include baseline "trip tables", or matrices of travel origins and destinations for the region's baseline land use, as well as "skim matrices" that capture travel time, distance and cost among travel origins and destinations for the MPO's existing or planned transportation infrastructure and services.

This allows the "8D" MXD and CAPCOA methods contained in UrbanFootprint to assess key factors related to regional accessibility and to translate vehicle trips between locations in the region into travel distance and VMT, and to do so consistently with the transportation system plans and modeling methods of the Vision California MPOs: SACOG, MTC, SCAG, SANDAG and the eight MPOs of the San Joaquin Valley.

UrbanFootprint also uses the MPO transportation networks to ascertain each regions transportation network supply, including the number of existing and future lane miles of freeway, arterials and local streets. This information, coupled with UrbanFootprint estimates of regional VMT, is used to estimate average regional travel speeds for purposes of refining the estimate of greenhouse gas and other emissions per VMT. These calculations are based on traffic data collected in over 100 regions across the US over the past 20 years by the Texas Transportation Institute (TTI) and the relationships between the TTI regional congestion indices and regional VMT per lane mile, as computed by the Oregon Department of Transportation for its GreenSTEP model.

Steps to Produce Travel Estimates in UrbanFootprint

Once a scenario has been created by running the core of the UrbanFootprint model to combine the attributes of future growth (as described using place types) with the attributes of the remaining no-change areas (which remain the same as in the base year), the travel engine can begin its work to produce estimates of travel behavior. (The travel engine can also run on the base year itself, for calibration purposes – the steps are the same.)

Analyze regional context

Travel distance and time measurements are "skimmed" from regional travel model transportation networks to produce matrices of zone-to-zone travel conditions. A variable-distance buffer is run to customize transport model results for each scenario's differing regional land use pattern. The tables are then adjusted to represent different variations in regional land use distributions that characterize different development scenarios. This is accomplished through a standard method of matrix rebalancing known as "Fratar factoring". In that the baseline MPO transport model skim tables may describe a differing land use future from the scenario being analyzed in UrbanFootprint, this step ensures that the variation is accounted for by counting up the amount of dwelling units and employment within a variable distance of each TAZ. Trip distance for each TAZ is the variable that is used to describe the buffer size (radius) for this operation. Inputs to this step are the skim tables from the regional travel model, as well as a future scenario in UrbanFootprint. The resulting adjusted skims represent the regional destination accessibility for each UrbanFootprint grid cell based on the regional land use distribution for the scenario under study.

Equation 7-1: Regional accessibility variable buffers

$$b_i(d) = \sum_j f_j\,(d)$$

$b_i = \ summed\ buffer\ value\ for\ feature\ i\ (grid\ cell)\ at\ distance\ d$

$f_j = \ feature\ value\ j\ from\ specified\ field$

$d = \ TAZ\ attractions\ trip\ distance\ from\ each\ feature$

Analyze local geographic context

Quarter-mile and whole-mile buffers around each grid cell or analysis unit are run to count total amounts of local destinations, which will be used to estimate the likelihood of walking, biking or taking transit for trips starting or ending there.

Equation 7-2: Local geographic context, one mile and one quarter mile buffers

$$b_i(d) = \sum_j f_j\,(d)$$

$b_i = summed\ buffer\ value\ for\ feature\ i\ (grid\ cell)\ at\ distance\ d$

$f_j = feature\ value\ j\ from\ specified\ fielddd = \ buffer\ distance\ from\ each\ feature$

Vehicle ownership

Vehicle ownership is estimated based on built environment D variables, household size, household income and other factors, and is used within MXD to compute the log odds of travel for each trip purpose. Calculation of vehicle ownership for MXD is accomplished using the model developed by the Southern California Association of Governments (SCAG) to capture the effects of D variables to evaluate the performance of its Sustainable Communities Strategy. The model was derived through analysis of 2009 National Household Travel Survey (NHTS) of 6700 households over the full range of urban, suburban and rural settings within the SCAG region. The model applies the following coefficients and parameters to variables describing the household demographic characteristics and the density, diversity, design, and transit service availability within ¼ mile buffers surrounding each household.

Table 7-6: Vehicle ownership coefficients

Variable	Coefficient	Variable	Coefficient
Number of Household Workers	.78503	Diversity by (Tier2 TAZ)	-.14735
Number of Household Members (< 16 yr old)	-0.00964	Density of intersections (3- and 4-leg)	-.00456
Number of Household Members (age 16-64)	.57486	Log of Frequent (≤20 min) Bus Stop density	-.03950
Number of Household Members (> 64 yr old)	.48015	Job/Household Ratio within 5 mile radius	-.04715
Median Household income in $10,000	.12982	Log H'hold Density within ½ mi of major bus	-.10478
Log (Household Density) within buffer	-.12171	Log H'hold Density within ½ mi of rail station	-.19649
Log (Job Density) within buffer	-.02131		

Table 7-7: Vehicle ownership parameters

Probable Range Parameter	Parameter
Mu(1): Parameter for auto ownership range between 1 and 2 vehicles	1.55972
Mu(2): Parameter for auto ownership range between 2 and 3 vehicles	3.02768
Mu(3): Parameter for auto ownership range above 3 vehicles	3.93686

The model is applied through the following equations:

Y^* = Sum (variable * coefficient)

$Y = 0$ if $Y^* \leq 0$
$Y = 1$ if $0 < Y^* \leq Mu(1)$
$Y = 2$ if $Mu(1) < Y^* \leq Mu(2)$
$Y = 3$ if $Mu(2) < Y^* \leq Mu(3)$

Where:
Y^* = vehicle ownership prediction variable as a function of all variables in table
$Y = 0$ is probability of owning zero vehicles as a function of Y^*
$Y = 1$ is probability of owning one vehicle as a function of Y^* and parameter Mu(1)
$Y = 2$ is probability of owning two vehicles as a function of Y^* and parameters Mu(1) and Mu(2)
$Y = 3$ is probability of owning two vehicles as a function of Y^* and parameters Mu(2) and Mu(3)

Base trip generation

Using ITE daily trip rate parameters and the equations below, base trips are generated for the land uses present in each grid cell. The base trips do not take into account the trip-reducing benefits of the 8Ds.

BTG(a) = LU(a) x ITE(a)
BTG (b) = LU(b) x ITE(b)
etc.

BTG = BTG(a) + BTG(b) + …

Where:
BTG = grid cell base trip generation
BTG(a) = base trip generation for grid cell land use type a
BTG(b) = base trip generation for grid cell land use type b
LU(a) = amount of land use type a grid cell
LU(b) = amount of land use type b grid cell
ITE(a) = trip generation rate for land use type a from ITE *Trip Generation Manual*
ITE(b) = trip generation rate for land use type b from ITE *Trip Generation Manual*

Total raw trips by purpose The total trips are sub-divided into trips for each of the principal travel purposes (commute, other home-based trips, non-home-based trips) using national survey values from the National Cooperative Highway Research Program (NCHRP) as averages based on area types.

HBWBTG = BTG * HBW%
HBOBTG = BTG * HBO%
NHBBTG = BTG * NHB%

Where:
BTG = grid cell base trip generation
HBWBTG = grid cell base daily home-based-work trip generation
HB0BTG = grid cell base daily home-based-other trip generation
NHBBTG = grid cell base daily non-home-based trip generation
HBW% = percent of trip generation made for home-based –work purpose for grid cell land uses

HBO% = percent of trip generation made for home-based –other purposes for grid cell land uses
NHB% = percent of trip generation made for non-home-based purposes for grid cell land uses

The HBO% and HBO% and NHB% factors are obtained from National Cooperative of Highway Professionals *Special Report 365*.
Home-based work, home-based other, non-home based trips are categorized as sets of productions (trips beginning or ending at a residence) and attractions (trips beginning or ending at a workplace, school, shopping, services, social, entertainment or recreational location).

Model variables and log odds calculations

The MXD method described above applies a series of equations to estimate the likely degree to which a development area's external traffic generation will be reduced due to: a) trip internalization, b) walking, or c) transit use for off-site travel. Equations for computing the trip reduction likelihoods have the following form:

Log Odds of (Internal Capture, Walk, Transit) = Constant + ∑ [Ln(VAR)*Coeff]

Where Ln indicates that the natural logarithm of taken of each built environment "D" variable (VAR), and the result is multiplied by a variable-specific coefficient (Coeff). The results of the individual calculation for each variable are summed and added to the Constant to produce the logarithmic odds of travel being, respectively, either internalized, pedestrian or transit.

HBWTG = HBWBTG – HBWInternal% - HWBWalk%-HBWTransit%
HBOTG = HBOBTG – HBOInternal% - HWOWalk%-HBOTransit%
NHBTG = NHBOBTG – NHBInternal% - NHBWalk%-NHBTransit%

Where:
HBWTG = grid cell daily home-based-work trip generation excluding internal, walk, transit trips
HB0TG = grid cell daily home-based-other trip generation excluding internal, walk, transit trips
NHBTG = grid cell daily non-home-based trip generation excluding internal, walk, transit trips
HBWBTG = grid cell base daily home-based-work trip generation
HB0BTG = grid cell base daily home-based-other trip generation
NHBBTG = grid cell base daily non-home-based trip generation
HBWInternal% = % of home-work trips remaining internal based on MXD log odds computation
HWBWalk% = % of external home-work trips by walk mode based on MXD log odds computation
HBWTransit% = % of external home-work trips by transit based on MXD log odds computation

VMT calculation (automobile trips)

The results of the calculation of each grid cell's vehicle trip generation are then multiplied by each cell's regional accessibility matrix, which quantifies the travel time to each other regional destination weighted by the attractiveness of that destination based on its land use intensity. The result is the amount of daily VMT generated by each cell, which is then summed to obtain total regional VMT.

HBWTL = Sum for all TAZs (TAZ Distance x TAZ HBW Attractions/Regional HBW Attractions)
HBOTL = Sum for all TAZs (TAZ Distance x TAZ HBO Attractions/Regional HBO Attractions)

NHBTL = Sum for all TAZs (TAZ Distance x TAZ NHB Attractions/Regional NHB Attractions)
VMT = (HBWTG x HBWTL) + (HBOTG x HBOTL) + (NHBTG x NHBTL)

Where:

VMT = Grid Cell Vehicle Miles Travelled
TAZ Distance = Distance from MPO model skim matrix from cell TAZ to each other regional TAZ
TAZ HBW Attractions = HBW attractions in TAZ from MPO HBW trip table
TAZ HBO Attractions = HBO attractions in TAZ from MPO HBO trip table
TAZ NHB Attractions = NHB attractions in TAZ from MPO NHB trip table
Regional HBW Attractions = Sum for all TAZ of HBW attractions from MPO HBW trip table
Regional HBO Attractions = Sum for all TAZ of HBO attractions from MPO HBO trip table
Regional NHB Attractions = Sum for all TAZ of NHB attractions from MPO NHB trip table

Other travel modes

The MXD calculations of walk and transit trips are also aggregated to regional totals of walk/bike and transit trips and consequent automobile mode share for the scenarios.

Regional VMT = Sum for all Cells: VMT

Regional Base Vehicle Trips = Sum for all Cells: BTG

Regional Walk/Bike Mode Share = Regional Walk/Bike Trips / Regional Base Vehicle Trips

Regional Transit Mode Share = Regional Transit Trips / Regional Base Vehicle Trips

Regional Walk/Bike Trips = Sum for all Cells:
[(HWBWalk% x HBWBTG) + (HBOWalk% x HBOBTG) + (NHBWalk% x NHBBTG)]

Regional Transit Trips = Sum for all Cells:
[(HBWTransit% x HBWBTG) + (HBOTransit% x HBOBTG) + (NHBTransit% x NHBBTG)]

Demand management effects

The first seven "D" variables are quantified by the MXD method at the local (grid-cell) level, allowing for differentiation amongst the performance of differing land uses by calculating the vehicle trip reductions resulting from the specific combination of extrinsic and intrinsic D variables that characterize each scenario, as described by combining Place Types (to describe future growth) with the base environment (no-change areas).

The effects of the 8th "D" variable, Demand Management, are quantified in UrbanFootprint at the regional level, using relationships reported in *Guidelines for Quantifying the GHG Effects of Transportation Mitigation*, published by CAPCOA. UrbanFootprint considers a set of demand management strategies relevant to regional planning and policy setting:

- Pricing measures applied as automobile operating cost increases

    - fuel charges
    - VMT charges
    - roadway tolling
- Transit level of service improvements
- Parking policies (including pricing)
- Employer trip reduction programs

The final results represent the total regional VMT for the transportation and land development scenario and demand management policies under study.

Demand Managed VMT = VMT x % Increase in Auto Operating Cost x CAPCOA Auto Cost Elasticity

or:
Demand Managed VMT = VMT x % Reduction in Transit Headways x CAPCOA Transit Headway Elasticity

or:
Demand Managed VMT = VMT x % Increase in Parking Charges x CAPCOA Parking Charge Elasticity

or:
Demand Managed VMT = VMT x % of Employees Provided Commute Alternatives x CAPCOA Employee Trip Reduction Program Elasticity

Where:
Increase in Auto Operating Cost = Sum of proposed % increase due to fuel charges, VMT charges, tolls

Validation of UrbanFootprint Sensitivity to Land Use Variations

UrbanFootprint estimates of VMT, vehicle trips and transit and non-motorized travel were validated through a series of regional and local Place Type tests. The regional testing included comparing the UrbanFootprint travel estimates to those produced by the MPOs state-of-practice regional transportation models, which are, themselves, validated with respect to traffic count data from the Caltrans Highway Performance Monitoring System (HPMS), transit ridership data and household travel surveys. These comparisons were used to verify UrbanFootprint's ability to replicate currently measured travel conditions in each region and to forecast change for future baseline scenarios in a manner consistent with the calibrated regional travel models developed under California Transportation Commission guidelines.

To assess UrbanFootprint's ability to capture travel variations associated with community level, and place-type local urban form, the 8D methods used in the model were validated in the following ways:

- Mapped Neighborhood-level VMT Variations – SACOG produces maps of VMT generation for households in all neighborhoods throughout the greater Sacramento region from its sophisticated, validated activity-based travel model. This mapping of variability of VMT generation by neighborhood, or traffic analysis zone, was compared with neighborhood VMT generation estimates produced by UrbanFootprint for Sacramento.

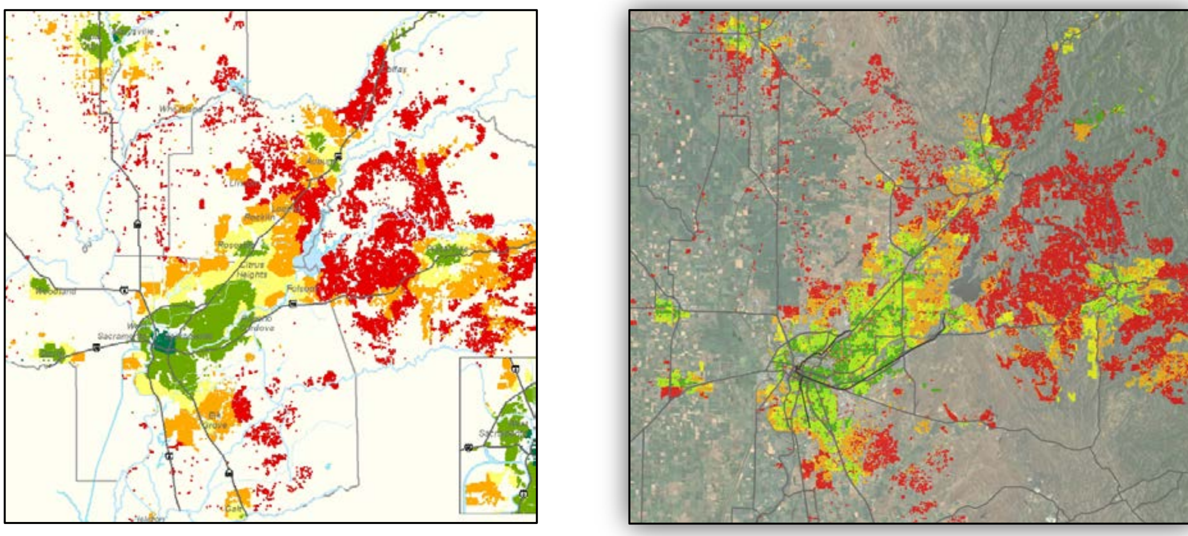


Figure 7-8: SACOG VMT per Household; SACSIM on the left, UrbanFootprint on the right; green is lower VMT/HH, red is higher.

- Community Types – Data developed by John Holtzclaw for his research on location efficient mortgages includes measures of annual VMT taken from Department of Motor Vehicles odometer data on vehicles in households within different communities in the Los Angeles and San Francisco regions. These data were compared against UrbanFootprint estimates of household VMT in the same communities or clusters of communities with similar built environment "D" variables.
- Place-Types – UrbanFootprint estimates of VMT generation for each of its over-30 Place Types were compared to household VMT reported in the National Household Travel Survey or most recent California Statewide Travel Survey for households located in settings comparable to each place-type description. Recognizing that a given Place Type generates different amounts of VMT depending on its location in the region, a range of VMT generation was expressed for each type, representing the difference in generation rates for the Place Type when located in regionally centric versus remote suburban settings. The range of VMT rates from the household survey were compared with the range of rates estimated by UrbanFootprint.

In each of these tests, the variation in trip generation throughout the region estimated by UrbanFootprint as a function of Place Type built environment compared well with the empirical travel data, demonstrating that the transportation model within UrbanFootprint produces reasonable sensitivity to fine-grained land use variations in addition to matching well at an aggregate level with the regional VMT and travel mode estimates from the MPO's state-of-practice regional transportation models.

Validation of UrbanFootprint Regional Travel Estimates

As a part of the Vision California project, the UrbanFootprint travel model was run for the five major regions of California (Sacramento, the San Francisco Bay Area, Southern California, San Diego and the eight counties of the San Joaquin Valley). The results were compared against published results for each region, as shown in Figure 7-9.

Base-Year Vehicle Miles Traveled (VMT) Validation Chart

Region	Base Year Validation Daily VMT	UrbanFootprint Modeled Base Year Daily VMT
Sacramento Area (6 Counties, SACOG)	50,040,540 (Fehr & Peers, SACOG - SACMET model, 2008 MTP)	53,632,530
San Francisco Bay Area (9 counties, ABAG/MTC)	143,681,890 (Fehr & Peers, MTC - MTC model, 2009 RTP)	143,784,640
Southern California (6 Counties, SCAG)	378,105,370 (Fehr & Peers, SCAG - SCAG model, 2008 RTP)	378,117,580
San Diego (SANDAG)	80,584,670 (Fehr & Peers, SANDAG - SANDAG model, 20011 RTP/SCS)	82,432,940
San Joaquin Valley (8 Counties)	114,532,890 (Fehr & Peers, UC Davis - CSTDM 2009 Model)	111,197,210

Figure 7-9: Travel Model Verification

Results are expected to vary by no more than 5% per standard travel model calibration practices, and UrbanFootprint in fact varies by much less than that for most of the regions.

References

Bochner, Brian; Hooper; Sperry; Dunphy; *Enhancing Internal Trip Capture Estimation for Mixed-Use Developments*, NCHRP Report 684, National Cooperative Highway Research Program, 2011

Ewing, R; Greenwald; Zhang; Walters; Feldman; Cervero; Frank; Thomas; *Traffic Generated by Mixed-Use Developments—A Six-Region Study Using Consistent Built Environmental Measures ASCE Planning Journal, Sept 2011,* UP0146

Fehr & Peers, *Southern California Association of Governments NHTS Model Documentation Report*, May 2012

Institute of Transportation Engineers; *Trip Generation*, Ninth Edition, 2012

Institute of Transportation Engineers; *Trip Generation Handbook*, Second Edition, 2004

San Diego Association of Governments, *Trip Generation for Smart Growth*, 2010

Transportation Research Board; *NCHRP Report 365 – Travel Estimation Techniques for Urban Planning,* 1998

CHAPTER 8
Transportation Impacts

UrbanFootprint calculates the energy use and related costs and emissions associated with light-duty passenger vehicle transportation. Scenarios vary in their transportation demand (measured in terms of vehicle miles traveled, or VMT) due to the impacts of land use on travel behavior. Greenhouse gas (GHG) emissions, criteria pollutant emissions, and transportation costs are, in turn, determined by policy-based assumptions about vehicle technology and performance standards, and the carbon intensity and cost of fuel and other transportation energy sources. This section details the policy-side assumptions and calculations used to model transportation impacts.

Transportation Energy Use

UrbanFootprint models transportation energy use, including fuel and electricity use, using assumptions about future on-road fleet characteristics. The technology and efficiency of new vehicles, as impacted by policy, have a significant impact on energy consumption and its related emissions. Changing vehicle standards are taken into account, along with detailed assumptions about fleet turnover (the rates at which cars are retired or scrapped, and new cars are purchased), to synthesize the composition and performance of the on-road vehicle population in the future. UrbanFootprint currently uses a standalone, spreadsheet-based fleet mix module to calculate the basic fleet characteristic inputs needed by the model[7]. This offers flexibility in specifying the level of detail of fleet characteristics.

On-Road Fleet Characteristics

The characteristics of the on-road fleet are represented in terms of average efficiency by vehicle type, and the relative proportion of that vehicle type on the road, in any given year. The model segments vehicles into technology categories, including:

- Gasoline internal combustion engines (including hybrid electric vehicles)
- Diesel internal combustion engines (including hybrid electric vehicles)
- Plug-in hybrid electric vehicles (gasoline or diesel)
- Battery electric vehicles
- Fuel cell and other zero-emission vehicles
- Alternative-fuel vehicles[8]

Autos and light trucks up to 8,500 pounds are included. Condensing the broad range of potential vehicle types into simplified categories enables users to vary assumptions for vehicle performance and sales at this level, rather than forcing them to specify assumptions for each and every vehicle type. If users want to model more specific fleet mix and technology scenarios, they can use UrbanFootprint's fleet mix

[7] This module will be integrated into UrbanFootprint in the near future, such that users can enter vehicle fleet assumptions, and see their effects on the on-road fleet in a scenario end-state year, via the model's user interface.

[8] Proposed for inclusion as a vehicle technology category, but not currently integrated in the fleet mix module.

module to process detailed inputs (including such figures as scrap rates by vehicle type and age) into the simplified fleet characteristics schema.

VMT is assigned to vehicles by category in direct proportion to their share of the on-road fleet. Thus, if battery electric autos comprise 14% of the fleet, they are assumed to travel 14% of total VMT. Plug-in hybrids are a unique category in that they use both gasoline and electricity. Estimates for fuel and electricity used by this vehicle category are based on an apportionment of miles to each energy source.

New Vehicle Performance and Fleet Turnover

On-road vehicle performance by type is calculated on the basis of new vehicle performance standards and assumptions about fleet turnover. The future fleet will be comprised of a variety of vehicle types, including but not limited to: gasoline-fueled internal combustion engine vehicles (including non-plug-in hybrids); diesel-fueled internal combustion engine vehicles (including non-plug-in hybrids); plug-in hybrid electric vehicles; battery electric vehicles; and fuel-cell vehicles. The performance standards of these vehicles – measured in miles per gallon (mpg) of gasoline or gasoline equivalent (mpge), or miles per kilowatt-hour of electricity (mpkWh) – will improve over time according to policies guided by emissions reductions goals. Assumptions for the performance of new vehicles, by model year and type, have been developed by federal and state agencies.

The California Air Resources Board uses the spreadsheet-based VISION model (developed by the U.S. Department of Energy Argonne National Laboratory) to model future vehicle scenarios. Similarly, the Energy Information Administration (EIA) produces "reference case" and other vehicle fleet scenarios for its Annual Energy Outlook. Values from these scenarios can be used as inputs to UrbanFootprint's fleet mix module. Table 8-1 shows the default vehicle type categories used by the VISION model, and their crosswalk into the simplified classification used by UrbanFootprint.

Table 8-1: Vehicle Type Categories in VISION model and UrbanFootprint

VISION Model Vehicle Types (Auto and Light Truck)		UrbanFootprint Vehicle Categories	Energy Source
Gasoline	Conventional Gasoline Vehicles	Internal combustion engine (ICE) - Gas	Gasoline
Gasoline SI HEV	Gasoline Hybrid Electric Vehicles		Gasoline
Diesel	Conventional Diesel Vehicles	Internal combustion engine (ICE) - Diesel	Diesel
Diesel HEV	Diesel Hybrid Electric Vehicles		Diesel
SI PHEV	Gasoline Plug-In Hybrid Vehicles	Plug-in hybrid electric (PHEV)	Gasoline and Electricity
Diesel PHEV	Diesel Plug-in Hybrid Vehicles		Diesel and Electricity
EV	Electric Vehicles	Battery Electric (BEV)	Electricity
EtOH	E-85 Ethanol Vehicles	Alternative fuel (AltFV)[9]	Gasoline equivalent
CNG	Compressed Natural Gas Vehicles		Gasoline equivalent
SI HEV E85	Gasoline/E-85 Flexible Fuel Hybrid Vehicles		Gasoline equivalent
FCV	Fuel Cell Vehicles	Fuel cell vehicles (FCV)	Gasoline equivalent

UrbanFootprint uses new vehicle sales rates, coupled with survival rates (using age categories going back 20 years), to estimate on-road vehicle population by category. The on-road population is quantified in terms of the number of vehicles of each model year and type that are in use in a given year. The fleet turnover assumptions are used along with the new vehicle performance assumptions to calculate on-road average performance by vehicle category. Auto ownership in each year is estimated by the UrbanFootprint travel engine, then passed into the fleet turnover module. Auto ownership impacts the fleet mix insofar as it determines the overall rate of vehicle turnover.

On-road fleet characteristics change from year to year on the basis of the input assumptions. Assumptions can be defined for specific horizon years – for instance, 2020, 2035, and 2050, or at five-year intervals – or for each year to the final scenario year. If stop points are entered, the model will estimate rates based on a simple linear trend between stop points. Fleet characteristics in years for which annual totals are not reported are significant to cumulative results, which express totals over many years (for instance, total fuel use from 2010 to 2050). Cumulative and interim-year results are not yet reported by the current version of UrbanFootprint (v1.0), but will be produced by future versions of the model.

Policy Basis for Assumptions

Table 8-2 shows a proposed framework of default vehicle fleet mix and performance assumptions for California that represent three distinct policy directions: business-as-usual (BAU) performance, adopted policy, and aspirational policy. Note that the proportion of on-road vehicles by the end-state year is the result of assumptions for new vehicle sales and turnover by category, by year.

[9] Proposed for inclusion in the UrbanFootprint fleet mix module.

Table 8-2: Vehicle Fleet Mix and Performance Assumptions Schema

	BAU		Adopted		Aspirational	
Vehicle Category	**Proportion of on-road vehicles in 2050**	**On-road average energy efficiency in 2050**	**Proportion of on-road vehicles in 2050**	**On-road average energy efficiency in 2050**	**Proportion of on-road vehicles in 2050**	**On-road average energy efficiency in 2050**
Auto/light truck average						
Internal combustion engines (ICE) – gasoline and diesel	99.7%	35.3 mpg	78%	35.3 mpg	5%	35.3 mpg
Hybrid electric vehicles	0.2%	55.8 mpg	4%	55.8 mpg	8%	59.5 mpg
Plug-in hybrid electric vehicles	0%	n/a	11%	58.2 mpg/ 1.6 mpkWh	27%	61.5 mpg/ 1.6 mpkWh
Battery electric vehicles	0%	n/a	7%	4.2 mpkWh	57%	4.2 mpkWh
Fuel cell and other zero-emission vehicles	0%	n/a	0%	96.6 mpg GE	3%	96.6 mpg GE

The BAU policy set is defined primarily for demonstration purposes, enabling a baseline comparison among scenarios. The Adopted policy set is intended to reflect currently adopted policy, with limited improvement occurring thereafter. Lastly, the Aspirational policy set reflects policies geared toward meeting California's goal of reducing greenhouse gas emissions to 80% below 1990 levels by 2050. In terms of vehicle fleet mix and performance, the policy sets are defined as follows:

- The BAU policy set assumes that no improvements are made in the base-year passenger vehicle fleet mix (or fuel mix) to 2050.This allows for a 'clean' policy-neutral analysis of the role of land use and transportation systems in scenarios without the impact of other policies.

- The Adopted policy set assumes a passenger vehicle fleet mix (defined by sales rates and new vehicle performance standards) that meets the California Governor's Executive Order for 1.5 million ZEVs on the road by 2025. The on-road new vehicle fleet average performance aligns with the EPA standard of 54.5 mpg by 2025[10] (with the assumption that real-world fuel economy is typically 20 percent lower). On-road fleet mix in 2050 is assumed to be composed of 78% internal combustion engine (ICE); 4% hybrids; 11% plug-in hybrids; and 7% battery electric vehicles.

- The Aspirational policy set assumes a passenger vehicle fleet mix (defined by sales rates and new vehicle performance standards) guided by the California ARB *Vision for Clean Air* Scenario 3[11], though with a transition to battery electric and plug-in-hybrid electric vehicles instead of fuel cell vehicles. On-road fleet mix in 2050 is assumed to be composed of 5% internal

[10] U.S. Environmental Protection Agency (EPA) and National Highway Traffic Safety Administration (NHTSA), 2012. *2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards, Final Rule*. Available at http://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/2017-25_CAFE_Final_Rule.pdf.

[11] California Air Resources Board, 2012. *Vision for Clean Air: A Framework for Air Quality and Climate Planning*. Report and model data available at www.arb.ca.gov/planning/vision/vision.htm.

combustion engine (ICE); 8% hybrids; 27% plug-in hybrids; 57% battery electric vehicles; and 3% other ZEV.

Transportation Energy Use Calculations

Transportation energy use is calculated on the basis of average on-road performance by vehicle type and energy source. For internal combustion engine vehicles, energy use is measured in terms of gallons of gasoline. For battery electric and plug-in hybrid electric vehicles, energy use is measured in terms of kilowatt-hours of electricity. For other non-electric vehicle types, such as fuel cell vehicles, energy use is measured in terms of gasoline equivalent. Equation 8-1 and Equation 8-2, respectively, show how transportation fuel and electricity use are calculated.

Equation 8-1: Annual transportation fuel consumption.

$$F_x = (M_{ICEx} * FE_{ICEx}) + (M_{Hx} * FE_{Hx}) + (M_{PHEVx} * FE_{PHEVx})$$

where:

F_x	=	Total transportation fuel use for a given scenario in year x
M_{ICEx}	=	VMT by conventional internal-combustion engine vehicles in year x (VMT by vehicle type is in direct proportion to share of on-road fleet mix)
M_{Hx}	=	VMT by gasoline/diesel hybrid electric vehicles in year x
M_{PHEVx}	=	VMT allocated to the fuel-using portion of plug-in hybrid electric vehicles in year x
FE_{ICEx}	=	On-road average fuel economy (mpg) of conventional internal-combustion engine vehicles in year x
FE_{Hx}	=	On-road average fuel economy (mpg) of hybrid electric vehicles in year x
FE_{PHEVx}	=	On-road average fuel economy (mpg) of the fuel-using portion of plug-in hybrid electric vehicles in year x
x	=	Any year in the model

Equation 8-2: Annual transportation electricity consumption.

$$F_x = (M_{EVx} * E_{EVx}) + (M_{PHEVx} * E_{PHEVx})$$

where:

K_x	=	Total transportation electricity use for a given scenario in year x
M_{EVx}	=	VMT by electric vehicles in year x (VMT by vehicle type is in direct proportion to share of on-road fleet mix)
M_{PHEVx}	=	VMT allocated to the fuel-using portion of plug-in hybrid electric vehicles in year x
E_{EVx}	=	On-road average vehicle efficiency of electric vehicles in year x
E_{PHEVx}	=	On-road average vehicle efficiency (mpkWh) of the electricity-using portion of plug-in hybrid electric vehicles in year x
x	=	Any year in the model

Greenhouse Gas Emissions from Transportation

GHG emissions from transportation include carbon dioxide equivalent (CO_2e) emissions from both upstream and downstream components of the energy lifecycle. Upstream emissions (also known as well-to-tank, or WTT emissions) include those associated with the production of energy, from material extraction to processing and transport. For electricity, this includes power plant emissions. Downstream emissions (tank-to-wheel, or TTW emissions) are those that occur upon energy use. For liquid fuels, this includes the emissions that occur upon fuel combustion. The emissions associated with electric and other alternative or "zero emission" vehicle use are primarily upstream.

As the vehicle fleet transitions to a greater proportion of electric and other alternative vehicle types, it becomes more important to account for "full fuel lifecycle" emissions from all transportation energy sources to allow for an accurate depiction of impacts. UrbanFootprint calculates upstream and downstream emissions separately according to energy consumption by source.

Note that, because UrbanFootprint does not load trips onto specific segments of the transportation system, it is not able to estimate local variations in vehicle speed, which is known to have an impact on vehicle emissions. GHG emissions estimates do not specifically account for the impact of congestion and vehicle speed, except to the extent that they are included as an average within other data sources used by the model.[12]

GHG Emissions Rates

Emissions rates are estimated according to assumptions about future fuel composition and the electricity generation portfolio mix. Upstream and downstream emissions rates for fuel pathways vary according to their composition of various energy feedstocks, from petroleum to biofuels such as cellulosic ethanol. Detailed inputs on the energy content and emissions impacts of the different feedstocks are provided by the Argonne National Laboratory Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model[13]. GHG emissions from electric vehicle use are calculated using the same emissions rates used for building electricity, which are based on specific assumptions about the mix of resources used to generate the electricity. Refer to the Energy Analysis Methodology for a detailed discussion of electricity emissions rates within UrbanFootprint.

Emissions rates for all energy sources are expected to decrease over time as the share of renewable energy sources increases. UrbanFootprint takes inputs for selected horizon years (e.g., 2020, 2035, and 2050), between which it assumes that rates follow a linear trend. The model can either calculate emissions rates based on fuel composition or energy mix inputs, or use predetermined rates.

Table 3 details a sample schema of assumption inputs for gasoline and diesel fuel composition at three horizon years that can be used to estimate carbon intensity. Other component fuels can be included in the mix by specifying the proportion of the fuel within the gasoline or diesel mix, its carbon intensity (in

[12] Future versions of the model will incorporate the impact of congestion estimated via volume-to-capacity ratios.

[13] CARB uses values calculated using the California-modified GREET (CA-GREET) model.

grams CO_2e per megajoule), its energy density (in mega-joules per gallon), and the proportion of its emissions attributable to the well-to-tank and tank-to-wheel portions of the fuel cycle[14].

Table 8-3: Fuel mix assumptions used to calculate CO_2e emissions factors

Fuel Mix Assumptions		2005	2020	2035	2050
Total Fuel Mix	**Percent Gasoline**	98.8%	98.2%	97.5%	96.5%
	Percent Diesel	1.2%	1.8%	2.6%	3.5%
Gasoline Fuel Mix	**% CARBOB[15]**	100%	80%	65%	50%
	% Ethanol	0%	0%	0%	0%
	% Cellulosic Ethanol	0%	20%	35%	50%
	Other (user-specified)	0%	0%	0%	0%
Diesel Fuel Mix	**% California ULSD (Petro)**	100%	85%	70%	50%
	% Biodiesel	0%	10%	5%	0%
	Other (user-specified)	0%	0%	0%	0%

Rates calculated by UrbanFootprint's GHG emissions rates module reflect CO_2e emissions per unit of energy (gallon of fuel, or kilowatt-hour of electricity). CO_2e emissions include carbon dioxide, nitrous oxide (N_2O), and methane (CH_4) emissions. Nitrous oxide and methane emissions are multiplied by the global warming potential (GWP) factors of 298 for nitrous oxide, and 25 for methane[16].

Policy Basis for Assumptions

Table 4 shows a proposed framework of default transportation emissions assumptions for California that represent three distinct policy directions: business-as-usual (BAU) performance, adopted policy, and aspirational policy. End-state targets are linked to specific years, with emissions rates in interim years calculated according to a straight-line trend between the targets. Note that the target years shown are flexible; targets can be set to any year, provided assumptions can be found or developed for the select target year(s).

[14] California Air Resources Board analysis and documentation for the Low Carbon Fuel Standard are available at http://www.arb.ca.gov/fuels/lcfs/lcfs.htm.

[15] California Reformulated Gasoline Blendstock for Oxygenate Blending (CARBOB) is a California-specific gasoline blend containing ethanol.

[16] Intergovernmental Panel on Climate Change. (2007). *Fourth Assessment Report.* Geneva: IPCC

Table 8-4: Transportation Energy Emissions Assumptions

		BAU	Adopted	Aspirational
Greenhouse Gas Emissions Rates				
Downstream (tank-to-wheel) Transportation fuel emissions (lbs CO2e/kWh)	Baseline	19.6 lbs/gal	19.6 lbs/gal	19.6 lbs/gal
	2020	19.6 lbs/gal	17.7 lbs/gal	17.7 lbs/gal
	2035	19.6 lbs/gal	17.7 lbs/gal	14.9 lbs/gal
	2050	19.6 lbs/gal	17.7 lbs/gal	6.5 lbs/gal
Transportation and residential & commercial building electricity emissions (lbs CO2e/kWh)	Baseline	0.81 lbs/kWh	0.81 lbs/kWh	0.81 lbs/kWh
	2020	0.81 lbs/kWh	0.61 lbs/kWh	0.61 lbs/kWh
	2035	0.81 lbs/kWh	0.61 lbs/kWh	0.43 lbs/kWh
	2050	0.81 lbs/kWh	0.61 lbs/kWh	0.056 lbs/kWh

The BAU policy set is defined primarily for demonstration purposes, enabling a baseline comparison among scenarios. The Adopted policy set is intended to reflect currently adopted policy, with limited improvement occurring thereafter. Lastly, the Aspirational policy set reflects policies geared toward meeting California's AB32 Greenhouse Gas reduction goal of reducing emissions to 80% below 1990 levels by 2050. In terms of building energy use, the policy sets are defined as follows:

- The BAU policy set assumes that no improvements are made in fuel or electricity emissions to 2050. This allows for a 'clean' policy-neutral analysis of the role of land use and transportation systems in scenarios without the impact of other policies.

- The Adopted policy set assumes that by 2020, the fuel mix used by internal combustion engine (ICE)/spark ignition vehicles – including gasoline and diesel – is assumed to meet a 10% reduction in carbon content from 2005, per the California Low Carbon Fuel Standard. The resulting emissions rate is held constant from 2020 to 2050. The electricity emissions rates are based on a projected resource mix that meets the California Renewables Portfolio Standard (RPS) goal of 33% renewable sources by 2020.

- The Aspirational policy set assumes that by 2050, the fuel mix will be comprised of 2/3 biofuels and 1/3 fossil fuels, per analysis of the pathway needed to achieve the AB32 reduction target[17]. The 2050 electricity emissions rates are based on a resource mix composed of 74% renewables by 2050[18].

[17] Williams, et al., 2011. The Technology Path to Deep Greenhouse Gas Emissions Cuts by 2050: The Pivotal Role of Electricity. *Science*.

[18] Maximum renewables potential estimated by Energy and Environmental Economics (E3) in their assessment of the energy policies and advancements required to meet California's GHG reduction goals. (Energy and Environmental Economics, 2009. *Meeting California's Long-Term Greenhouse Gas Reduction Goals.)*

Transportation GHG Emissions Calculations

GHG emissions from transportation energy use are calculated on the basis of energy use by source, and emissions rates per unit of energy. Emissions are calculated for liquid fuels (gasoline and diesel), electricity, and other sources measured in gasoline equivalent.

CO_2e emissions for both well-to-wheel (full lifecycle) and tank-to-wheel (combustion only) fuel emissions are calculated as shown in Equation 3.

Equation 8-3: Annual GHG (CO_2e) emissions from LDV fuel or electricity consumption.

$$G_x = (F_x * R_{Fx}) + (K_x * R_{Kx})$$

where:

G_x	=	Total transportation GHG emissions for a given scenario in the year x
F_x	=	Total transportation fuel use for a given scenario in the year x
R_{Fx}	=	Rate of CO_2e emissions per gallon in the year x (downstream, upstream, or full lifecycle emissions)
K_x	=	Total transportation electricity use for a given scenario in the year x
R_{Kx}	=	Rate of CO_2e emissions per kilowatt-hour in the year x (upstream emissions)
x	=	Any year in the model

Criteria Pollutant Emissions from Transportation

Criteria pollutant emissions from transportation include nitrogen oxides (NO_x), sulfur oxides (SO_x), carbon monoxide (CO), volatile organic compounds (VOC), and particulate matter ($PM_{2.5}$ and PM_{10}). UrbanFootprint currently models on-road, mobile-source emissions only; upstream emissions associated with energy generation are not calculated by the current version of the model (v1.0). On-road air pollutant emissions are used as a basis for estimating respiratory health impacts and associated costs.

Note that, because UrbanFootprint does not load trips onto specific segments of the transportation system, it is not able to estimate vehicle speed, which is known to have an impact on vehicle emissions. Thus, as for GHG emissions, criteria pollutant emissions estimates do not specifically account for the impact of congestion and vehicle speed, except to the extent that they are included as an average within other data sources used by the model.[19]

Criteria Pollutant Emissions Rates

UrbanFootprint currently applies different rates of emissions to travel by internal combustion engine (ICE) vehicles and zero-emission vehicles. Per-mile emissions from ICE vehicles are expected to decrease steadily over time as fuel economy increases, fuels get cleaner, and vehicle technology improves. Per-mile emissions from "zero-emission" vehicle types, such as electric and fuel cell vehicles, only include particulate matter emissions resulting from tire wear.

[19] Future versions of UrbanFootprint will account for the impacts of vehicle speed on criteria pollutants based on estimates of congestion via volume-to-capacity ratios at a regional level.

Policy Basis for Assumptions

To calculate emissions from ICE vehicle travel, and tire wear from zero-emission vehicle travel, UrbanFootprint is loaded with per-mile emissions rates calculated using the CARB Emission Factors Model (EMFAC 2011). EMFAC 2011 reflects the latest adopted policies in California, including the Low Carbon Fuel Standard and the Pavley Clean Car Standard. EMFAC was run using statewide default assumptions to determine California average criteria pollutant emissions for the passenger vehicle fleet, including cars and light trucks up to 8,500 lbs (EMFAC vehicle categories LDA, LDT1, LDT2, and MDV). For regional or local work, EMFAC can be used to produce emissions rates at the county and sub-area (intersection of county and air basin) scales.

Criteria Pollutant Emissions Calculations

Criteria pollutant emissions from transportation energy use are calculated on the basis of miles traveled by vehicle type (ICE or ZEV) and emissions rates per mile, as shown in Equation 4.

Equation 8-4: Annual criteria pollutant emissions from LDV travel.

$$P_{px} = (T_{Fpx} * R_{Fpx}) + (T_{ZEVpx} * R_{ZEVpx})$$

where:

P_{px}	=	Emissions of criteria pollutant p in a given scenario in the year x
T_{Fpx}	=	LDV VMT by fuel-using vehicles for a given scenario for the year x
R_{Fpx}	=	Rate of criteria pollutant p emissions per mile for fuel-using vehicles for the year x
T_{ZEVpx}	=	LDV VMT by zero-emission vehicles for a given scenario for the year x
R_{ZEVpx}	=	Rate of criteria pollutant p emissions per mile for ZEV vehicles for the year x
x	=	Any year for which data for both T and R are available

Transportation Costs

UrbanFootprint calculates household costs associated with light-duty vehicle travel, including fuel and transportation electricity costs, and costs related to auto ownership and maintenance. These costs are calculated on the basis of VMT and energy consumption by vehicle type. While the model is not currently sensitive to pricing strategies – that is, it does not link transportation costs to driving behavior – this can be discussed as a potential functionality.[20]

Transportation Cost Factors

Transportation energy cost factors are the projected retail prices for transportation fuel and electricity. Fuel costs are expressed in terms of dollars per gallon, while electricity costs are expressed in dollars per kilowatt-hour (kWh). Cost assumptions are input for selected horizon years, with a linear trend assumed to happen between them. Electricity costs are assumed to be the same as for residential building energy use.

[20] Future versions of the model can incorporate logic that builds out the effects of increasing the cost of driving at the local level, the regional level or both.

Auto ownership costs include the cost of a vehicle, plus finance charges, insurance, registration, and other associated fees, while auto maintenance costs include those for tires, routine maintenance, and repairs. Ownership and maintenance costs are calculated on the basis of an average cost per mile traveled. Costs can be disaggregated in order to allow users to apply pricing sensitivity to maintenance costs (as a "discretionary" cost) alone.

Note that all cost assumptions and metrics in UrbanFootprint are expressed in terms of constant dollars. Typically, costs are expressed in constant dollars, such that future-year costs are expressed in terms of today's dollars (for example, projected gas prices in 2050 are expressed in 2012 dollars).

Policy Basis for Assumptions

Energy costs are subject to a number of factors, and understandably cannot be predicted with accuracy. Historical data could be used to predict trend-based price increases, but the overall energy outlook makes it unlikely that past trends will hold into the future. These costs may be related to vehicle fleet mix and performance projections. Users can specify horizon-year prices at their choosing, in terms of constant dollars.

Auto ownership and maintenance costs are assumed to remain steady over time, and to be the same across vehicle types. Different costs can be associated with different vehicle types, if a basis for these assumptions exist.

Transportation Cost Calculations

The model calculates the costs associated with transportation fuel and electricity use by applying per-gallon or per-kWh prices to the amount of fuel or electricity consumed. Auto ownership and maintenance costs are calculated by applying per-mile costs to VMT. Equations 5 and 6, respectively, demonstrate the total annual cost calculations for transportation energy and ownership/maintenance.

Equation 8-5: Annual transportation energy cost.

$$D_x = (F_x * P_{Fx}) + (K_x * P_{Kx}) + (GE_x * C_{GEx})$$

where:

D_x = Total dollars spent on transportation energy for a given scenario in the year x

F_x = Transportation fuel consumption for a given scenario in the year x

P_{Fx} = Fuel price per gallon (in constant dollars) for the year x

K_x = Transportation electricity consumption for a given scenario in the year x

P_{Kx} = Electricity price per kilowatt-hour (in constant dollars) for the year x

x = Any year for which data for both F and P are available

Equation 8-6: Annual auto ownership and maintenance cost.

$$O_x = M_x * C_x$$

where:

O_x = Total dollars spent on auto ownership and maintenance for a given scenario in the year x

M_x = Total annual VMT for a given scenario in the year x

C_x = Auto ownership and maintenance cost per mile (in constant U.S. dollars) for the year x

x = Any year for which data for both M and C are available

CHAPTER 9
Building Energy Impacts

UrbanFootprint models building energy use, and related costs and greenhouse gas (GHG) emissions, for all new and existing residential and commercial buildings. Scenarios vary in their building energy use profiles due to their building program, the location of new growth, and policy-based assumptions for improvements in energy efficiency. The costs and GHG emissions associated with energy use, in turn, vary according to policy-based price and emissions rate assumptions. This section details the assumptions and calculations used to model building energy demand and its associated impacts.

Building Energy Use

Within the model, energy use is determined by three types of variables: building characteristics, climate zone, and efficiency factors. Building characteristics and climate zone determine what baseline per-residential unit or per-commercial square foot factors (derived from survey data) are used to calculate energy use. Reductions are then applied to the resulting baseline estimates to reflect the implementation of building efficiency and conservation policies into the future.

Baseline Energy Use

This section outlines the basis for the model's baseline energy use factors, which quantify electricity and natural gas demand per residential unit or commercial square foot by building type and climate zone. Building characteristics are tied to scenario composition, while climate zone is location-dependent.

Building Types

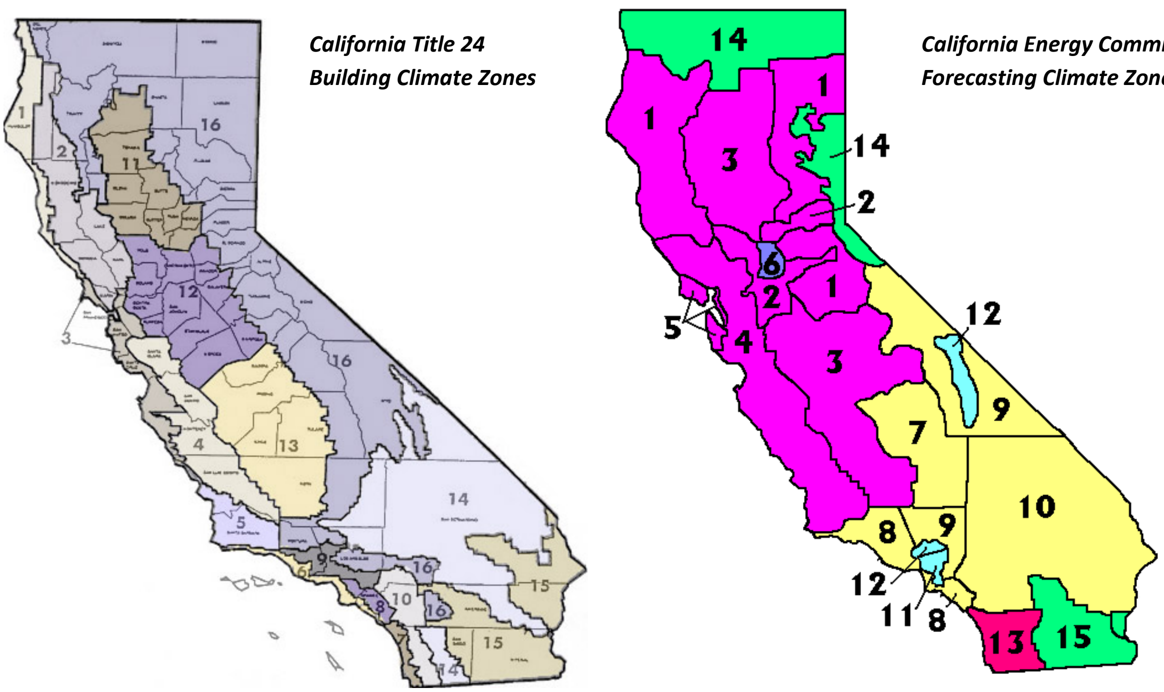
Through the application of place and building types, UrbanFootprint details scenarios in terms of their component building characteristics, which are the foundation for estimating energy use. Residential units are classified by type, including small- and large-lot single family, townhome, and multifamily. Commercial buildings are described in terms of square footage by use category – including subcategories of retail, office, and other non-residential types – which are linked to numbers of jobs by employment sector. The numbers of residential units and amounts of commercial square feet per acre of a given place type are grounded in its specific mix of building types.

The energy required to serve the same numbers of homes and jobs varies by scenario due to the types of buildings assumed to accommodate them (as well as location and policy factors). While a number of factors contribute to energy consumption patterns, residential energy use varies significantly by home size, with more spacious and detached units requiring more energy. Similarly, commercial energy use is linked to building size. Thus, scenarios that include more compact development patterns and building types generally exhibit lower energy use profiles than more dispersed scenarios.

Climate Zones

Energy use is also dependent on location due to variations in climate characteristics, which affect heating and cooling needs – a major determinant of electricity and natural gas use. In California, two sets of climate zones are used, both established by the California Energy Commission (CEC). Residential and commercial energy use data in California is classified by these climate zones. Title 24 Building Standard climate zones are used for residential energy use factors, while Forecasting Climate Zones (FCZs) are used as the basis for commercial energy use factors. Figure 9-1 shows the two sets of climate zones used in California scenarios.

Figure 9-1: California Climate Zones



Residential Energy Baselines

Baseline residential energy use factors specify the amount of electricity and natural gas used annually per housing unit, by housing type and climate zone. For California, UrbanFootprint uses factors based on California Energy Commission (CEC) Residential Appliance Saturation Survey data[21]. These factors represent base-year energy use (the most recent RASS data is from 2009), with future-year energy use estimated in terms of reductions from base year estimates. Note that, while the specifics of using RASS data are described here, alternative baseline factors can be loaded into the model to reflect data tuned to the scale and location of scenarios to be developed and analyzed.

RASS data can be filtered by a range of geographic, building, and household characteristics. Per-unit baselines are estimated by summarizing the data by climate zone, building type, and square footage. For energy modeling purposes, UrbanFootprint classifies the single family detached types into two simple categories: small lot and large lot. Table 1 shows how the RASS building type and unit size categories are associated with the UrbanFootprint building types.

[21] California Energy Commission. (2010). California Statewide Residential Appliance Saturation Survey (RASS). Sacramento: CEC.

Table 9-1: RASS categories used for UrbanFootprint residential types (Statewide average values shown as samples)

UrbanFootprint Building Type	Simplified UrbanFootprint Residential Building Type	RASS Categories	Annual Electricity Use Factor (kWh/unit)	Annual Gas Use Factor (therms/unit)
Mixed Use Types				
Skyscraper Mixed Use	Multifamily	Apt/Condo 5+	3,790 kWh	243 thm
High-Rise Mixed Use	Multifamily	Apt/Condo 5+	3,790 kWh	243 thm
Mid-Rise Mixed Use	Multifamily	Apt/Condo 5+	3,790 kWh	243 thm
Low-Rise Mixed Use	Multifamily	Apt/Condo 5+	3,790 kWh	243 thm
Parking Structure/Mixed Use	Multifamily	Apt/Condo 5+	3,790 kWh	243 thm
Main Street Commercial/MU High	Multifamily	Apt/Condo 5+	3,790 kWh	243 thm
Main Street Commercial/MU Low	Multifamily	Apt/Condo 5+	3,790 kWh	243 thm
Residential Types				
Skyscraper Residential	Multifamily	Apt/Condo 5+	3,790 kWh	243 thm
High-Rise Residential	Multifamily	Apt/Condo 5+	3,790 kWh	243 thm
Urban Mid-Rise Residential	Multifamily	Apt/Condo 5+	3,790 kWh	243 thm
Urban Podium Multi-Family	Multifamily	Apt/Condo 5+	3,790 kWh	243 thm
Standard Podium Multi-Family	Multifamily	Apt/Condo 5+	3,790 kWh	243 thm
Suburban Multifamily Apt/Condo	Multifamily	Apt/Condo 5+	3,790 kWh	243 thm
Urban Townhome/Live-Work	SF Attached	Townhouse	4,915 kWh	332 thm
Standard Townhome	SF Attached	Townhouse	4,915 kWh	332 thm
Garden Apartment	Multifamily	Apt/Condo 5+	3,790 kWh	243 thm
Very Small Lot 3000	SF Small Lot	SF 1250-2000 sqft	7,150 kWh	389 thm
Small Lot 4000	SF Small Lot	SF 1250-2000 sqft	7,150 kWh	389 thm
Medium Lot 5500	SF Small Lot	SF 1250-2000 sqft	7,150 kWh	389 thm
Large Lot 7500	SF Large Lot	SF 2000+ sqft	9,645 kWh	504 thm
Estate Lot	SF Large Lot	SF 2000+ sqft	9,645 kWh	504 thm
Rural Residential	SF Large Lot	SF 2000+ sqft	9,645 kWh	504 thm
Rural Ranchette	SF Large Lot	SF 2000+ sqft	9,645 kWh	504 thm

Currently, the link between household size and unit type is implicitly linked to current occupancy characteristics. The model will be enhanced to use coefficients to link the per-unit residential energy use factors more explicitly to household size. The derivation of these coeffficients may be based on analysis of existing RASS data.

Estimating energy consumption for multifamily building common areas

The RASS unit consumption factors capture the energy use within dwelling units only. In order to represent the total building energy use associated with dwelling units in multifamily and mixed-use residential buildings, the energy requirements of common spaces (e.g., hallways, lobbies) is estimated using an energy intensity (EI) factor derived from CEC Commercial End-Use Survey (CEUS) data for buildings in the 'Lodging' category.

This EI factor is the sum total of the CEUS Lodging building EIs for the following end-use categories: heating, cooling, ventilation, lighting, motors, and air compressors, as identified in Table 9-2. In addition, 25% of the 'Miscellaneous' category EI is included. This approach is intended to capture major energy draws – space conditioning, lighting, and elevators – as well as the requirements for common area equipment. The total EI is then reduced by 60%[22] to arrive at a final proxy factor for residential common areas.

Table 9-2: CEUS-based calculation used to estimate the energy intensity of common areas in multifamily buildings

Annual Electric Summary Statistics: CEUS Lodging Category (Statewide Average)			
End Use	**EI Energy Intensity (kWh/Segment FS/Year)**	**75% reduction applied to Misc category**	**60% overall reduction applied**
Heating	0.42 kWh		0.17 kWh
Cooling	2.41 kWh		0.96 kWh
Ventilation	1.79 kWh		0.71 kWh
Water Heating	0.03 kWh		
Cooking	0.68 kWh		
Refrigeration	0.90 kWh		
Exterior Lighting	0.61 kWh		0.24 kWh
Interior Lighting	3.50 kWh		1.40 kWh
Office Equipment	0.17 kWh		
Miscellaneous	1.11 kWh	0.28 kWh	0.11 kWh
Process	0.00 kWh		
Motors	0.48 kWh		0.19 kWh
Air Compressors	0.02 kWh		0.01 kWh
Residential common areas proxy			**3.80 kWh/sq ft**

Using this proxy EI factor, coupled with assumptions about building size and the proportion of common areas to net residential unit area within buildings (generally 85% net residential, 15% common area) this component of energy demand can be calculated. This component is added to the per-unit energy demand factors to arrive at the total residential energy demand per acre for a building type. The commercial energy demand component of mixed-use buildings is calculated separately.

Commercial Energy Baselines

Baseline commercial energy use factors specify the amount of electricity and natural gas used annually per square foot for commercial buildings. In California, these rates are based on CEC Commercial End-

[22] Estimates for adapting CEUS data for multifamily building common areas were based on guidance from Robert Ramirez at Itron, Inc.

Use Survey (CEUS) data[23]. The CEUS provides energy intensities (EI) – energy use per square foot – by end use for 14 building types, classified by CEC Forecasting Climate Zone. UrbanFootprint uses total energy intensities to include all end uses surveyed. Note that, while the specifics of using CEUS data are described here, alternative baseline factors can be loaded into the model to reflect data tuned to the scale and location of scenarios to be developed and analyzed.

Table 9-3 shows the schema of the CEUS commercial energy use factors. These factors represent base-year energy use (the most recent CEUS data is from 2006). These factors are applied to the floor space in each of these categories, as estimated by UrbanFootprint.

Table 9-3: CEUS Commercial Energy Intensity by Zone and Building Type (kWh/square foot)

	CEUS Building Categories										
Forecasting Climate Zone	Small Office	Large Office	Restaurant	Retail	Food Store	Warehouse	School	College	Health	Lodging	Misc
1	14.4	9.1	27.6	17.3	36.8	14.6	8.7	12.9	14.6	9.3	5.2
2	11.9	12.6	35.8	14.9	44.6	8.4	7.1	11.8	17.6	8.8	10.0
3	9.4	14.2	33.2	10.1	36.3	22.7	8.8	14.2	15.0	10.1	10.4
⋮											
15	14.5	15.2	31.4	12.6	40.3	7.7	5.5	12.7	18.4	10.0	9.0

UrbanFootprint estimates building square footage by employment category for the base year by applying per-employee floor space assumptions to job totals. For future scenario years, floor space is first estimated by broad employment sector (retail, office, industrial) through the application of place and building types, which specify their spatial proportions within buildings. Location-specific employment data are then used to further apportion floor space among the CEUS categories.

Energy Efficiency Policy Options

Energy efficiency policies are a major determinant of building energy use. This section describes the framework of assumptions applied by the model to reflect the impact of various energy efficiency and conservation policies into the future. New buildings are expected to meet increasingly higher standards for new construction, while the population of existing buildings is expected to exhibit improved performance as a result of buildings being either renovated, retrofitted, or replaced.

Building Stock Categorization

The stock of residential and commercial buildings is subject to ongoing changes, as new construction, retrofits, and building replacement occurs. UrbanFootprint tracks the amounts of residential units and commercial floor space in each of these building populations. The numbers of buildings that are built or demolished (through redevelopment) result from the application of place types to the landscape (scenario development). The numbers of buildings that are either retrofitted or replaced are determined by assumed rates, which can be varied to reflect the effects of policies that incentivize efficiency improvements for existing buildings. Finally, some amount of buildings – the remainder – can be

[23] California Energy Commission. (2006). California Commercial End-Use Survey (CEUS). Sacramento: CEC.

assumed not to change. Figure 9-2 illustrates an example of how residential building stock can change within a grid cell.

Going forward, each segment of the building population is subject to differing rates of improvement, as specified by energy efficiency factors. Specific policy options for use in California are outlined following the description of the efficiency factors.

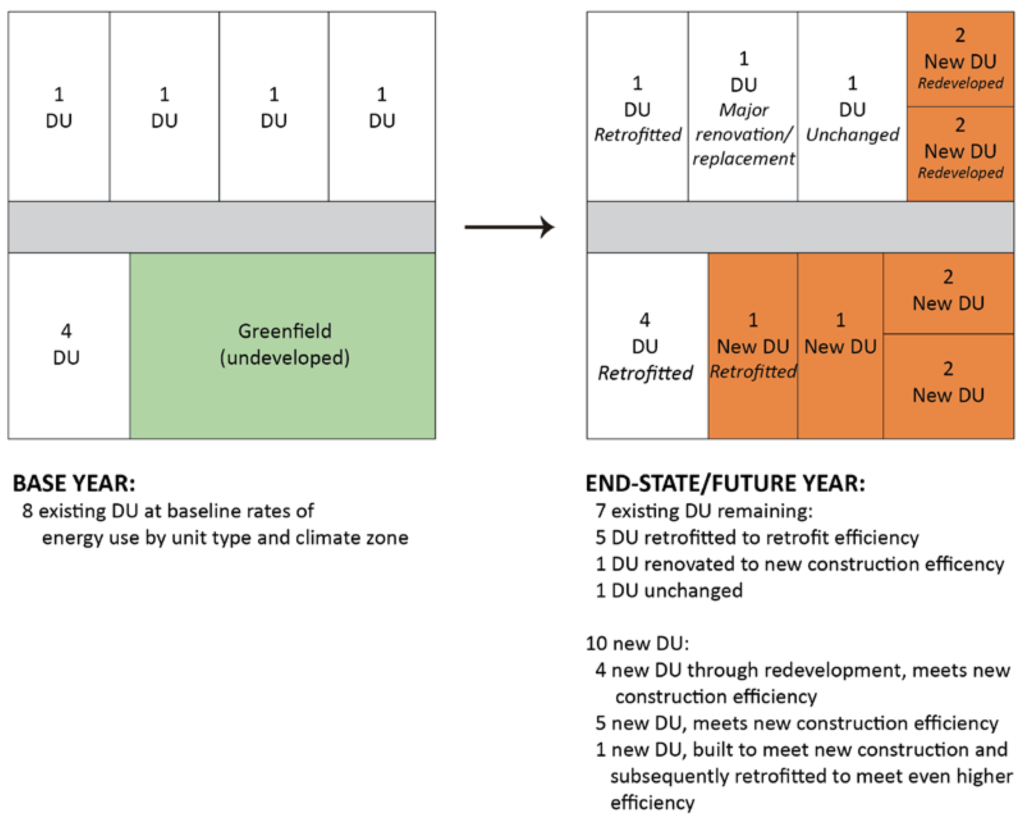


Figure 9-2: Residential building stock change within a grid cell

Energy Efficiency Factors

Two different types of energy use reduction factors are applied to express the effects of policy implementation on the various populations of new and existing buildings: 1) new construction efficiency, which is applied to reflect the implementation of higher efficiency standards and policies into the future; and 2) retrofit efficiency, which is applied to reflect energy savings due to building improvements made through retrofits and minor renovations.

New Construction Efficiency

New construction includes new buildings and wholesale replacement and major renovations. This includes buildings built on greenfield land, those constructed through infill or redevelopment, and those built as replacements of existing buildings – each of these categories are treated as new construction. The "new construction efficiency" factor can be set to reflect specific energy-saving policies for new construction, such as California's Title 24 building standards, as well as local green building codes. The factor is expressed as a set of horizon-year energy use reduction targets (e.g., for 2020, 2035, and 2050) from baseline energy use. Different sets of targets can be applied to test specific policies for residential and commercial energy use, and the electricity and natural gas components of each.

Between horizon-year targets, the reductions are assumed to deepen at a steady rate. Thus, a multifamily unit built in 2025 would use less energy per year than the same type of unit built in 2015 – a rate which persists thereafter. By default, growth is assumed to occur at a steady rate between horizon years – that is, an equal number of units are allocated to each year over a defined period, though assumptions about the pace of new growth can be varied.

Within UrbanFootprint, a spreadsheet-based module is used to project forward the effects of deepening reductions over time to an end-state year – or in other words, convert horizon-year reduction targets into effective end-state reductions.

Table 9-4 shows a sample of this conversion (populated with demonstration values), in which a policy for new construction efficiency meets a 20% reduction by 2020, a 50% reduction by 2035, and an 80% reduction by 2050. The resulting rate, to be applied to all homes constructed over the period 2010 to 2050, is 41%.[24]

Retrofit Efficiency

Energy use in the population of existing buildings can be expected to decline over time as a result of buildings being retrofitted to achieve greater energy performance. Similarly, energy use in the population of "new" buildings (those built within the time span of a scenario) can be expected to be further reduced due to retrofits in years subsequent to their construction. The number of homes, or amount of commercial floor space, that undergo retrofits is determined by a retrofit rate assumption, taken as a percentage of building stock in each year. (This retrofit rate is also used in building water use calculations.)

The model uses a "retrofit efficiency" factor to reflect the savings potentials for residential and commercial electricity and natural gas use. This factor is expressed in terms of horizon-year target reductions from baseline (the same way that the new construction efficiency factor is expressed). The resulting end-year reductions are applied to the numbers of new and existing buildings that are assumed to be retrofitted over time.

[24] Future versions of UrbanFootprint will incorporate functionality to calculate annual metrics for each year between a scenario base year and end-state year, enabling interim-year and cumulative total results reporting.

Table 9-4: Conversion of horizon-year target reductions to effective end-state reductions.

Year	Energy efficiency factor – (Target reduction INPUT)	New Units built in year	Total Units	Baseline energy use per unit	Efficient energy use per unit (energy reduction applied)	Vintage totals – total energy used by buildings constructed within a year[25]	Annual total – total energy used by buildings of all ages	Average energy use per unit	Effective end-year efficiency reduction
2010	0%	0	0	100 thm	100 thm	0 thm	0 thm	0 thm	0%
2011	2%	2,500	2,500	100 thm	98 thm	245,000 thm	245,000 thm	98 thm	-2%
2012	4%	2,500	5,000	100 thm	96 thm	240,000 thm	485,000 thm	97 thm	-3%
2013	6%	2,500	7,500	100 thm	94 thm	235,000 thm	720,000 thm	96 thm	-4%
2014	8%	2,500	10,000	100 thm	92 thm	230,000 thm	950,000 thm	95 thm	-5%
2015	10%	2,500	12,500	100 thm	90 thm	225,000 thm	1,175,000 thm	94 thm	-6%
2016	12%	2,500	15,000	100 thm	88 thm	220,000 thm	1,395,000 thm	93 thm	-7%
2017	14%	2,500	17,500	100 thm	86 thm	215,000 thm	1,610,000 thm	92 thm	-8%
2018	16%	2,500	20,000	100 thm	84 thm	210,000 thm	1,820,000 thm	91 thm	-9%
2019	18%	2,500	22,500	100 thm	82 thm	205,000 thm	2,025,000 thm	90 thm	-10%
2020	20%	2,500	25,000	100 thm	80 thm	200,000 thm	2,225,000 thm	89 thm	**-11%**
2021	22%	2,500	27,500	100 thm	78 thm	195,000 thm	2,420,000 thm	88 thm	-12%
⋮									
2034	48%	2,500	60,000	100 thm	52 thm	130,000 thm	4,500,000 thm	75 thm	-25%
2035	50%	2,500	62,500	100 thm	50 thm	125,000 thm	4,625,000 thm	74 thm	**-26%**
2036	52%	2,500	65,000	100 thm	48 thm	120,000 thm	4,745,000 thm	73 thm	-27%
⋮									
2049	78%	2,500	97,500	100 thm	22 thm	55,000 thm	5,850,000 thm	60 thm	-40%
2050	80%	2,500	100,000	100 thm	20 thm	50,000 thm	5,900,000 thm	59 thm	**-41%**

Policy Basis for Assumptions

[25] This is like the concept of a vehicle model year. The total for 2015, for example, represents the total annual amount of energy used by all year-2015 vintage buildings (each of which is built to use 10% less than the 2010 baseline – an enduring performance characteristic) going forward.

Table 9-5 shows a proposed framework of default building energy use assumptions for California that represent three distinct policy directions: business-as-usual (BAU) performance, adopted policy, and aspirational policy. End-state targets are linked to specific years. Energy use in interim years is calculated according to a straight-line trend between the targets. Note that the target years shown are flexible; targets can be set to any year, provided assumptions can be found or developed for the select target year(s).

Table 9-5: Building Energy Efficiency and Turnover Assumptions

	Target Year	BAU		Adopted		Aspirational	
		Electricity	Natural Gas	Electricity	Natural Gas	Electricity	Natural Gas
Residential Buildings							
New/Redeveloped/Replaced Residential Construction Efficiency (% reduction from baseline)	2020	0%	0%	-25%	-25%	-50%	-65%
	2035	0%	0%	-30%	-30%	-65%	-80%
	2050	0%	0%	-35%	-35%	-80%	-95%
Residential Retrofit Efficiency (% reduction from baseline)	2020	0%	0%	-15%	-15%	-20%	-35%
	2035	0%	0%	-20%	-20%	-40%	-55%
	2050	0%	0%	-30%	-30%	-60%	-75%
Percent of base/existing residential buildings retrofitted each year	All years	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
Percent of base/existing residential buildings replaced each year	All years	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%
Percent of new residential buildings that are subsequently retrofitted	All years	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%
Commercial Buildings							
New/Redeveloped/Replaced Commercial Construction Efficiency (% reduction from baseline)	2020	0%	0%	-40%	-40%	-50%	-50%
	2035	0%	0%	-60%	-60%	-65%	-65%
	2050	0%	0%	-60%	-60%	-80%	-80%
Commercial Retrofit Efficiency (% reduction from baseline)	2020	0%	0%	-15%	-15%	-20%	-20%
	2035	0%	0%	-25%	-25%	-40%	-40%
	2050	0%	0%	-40%	-40%	-60%	-60%
Percent of base/existing commercial floor space retrofitted each year	All years	0.95%	0.95%	0.95%	0.95%	0.95%	0.95%
Percent of base/existing commercial floor space replaced each year (EXCLUDING redevelopment)	All years	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
Percent of new commercial buildings that are subsequently retrofitted	All years	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%

The BAU policy set is defined primarily for demonstration purposes, enabling a baseline comparison among scenarios. The Adopted policy set is intended to reflect currently adopted policy, with limited improvement occurring thereafter. Lastly, the Aspirational policy set reflects policies geared toward meeting California's goal of reducing greenhouse gas emissions to 80% below 1990 levels by 2050. In terms of building energy use, the policy sets are defined as follows:

- The BAU policy set assumes that no improvements are made in building energy performance to 2050. This allows for a 'clean' policy-neutral analysis of the role of land use and transportation systems in scenarios without the impact of other policies.

- The Adopted policy set assumes that new homes ramp down to using 35% less energy than baselines by 2050, while existing homes use 30% less, due to building energy efficiency policies for new construction, retrofits, and replacements/major renovations. The commercial energy efficiency assumptions are slightly stronger than the residential assumptions, with new buildings ramping down to 60% below baseline by 2050, and existing buildings using 40% less.

- The Aspirational policy set assumes that new homes ramp to 80% less energy than baselines by 2050, and existing buildings use 60% less, due to building energy efficiency policies for new construction and renovations/retrofits. Aspirational policy also assumes different reductions for electricity vs. natural gas use to reflect a shift in home energy use from natural gas to electricity. The commercial energy efficiency assumptions align with the residential assumptions, with new buildings ramping to 80% below baseline by 2050, and existing buildings using 60% less. In combination with commercial energy use, this aligns with an aspirational goal of overall energy efficiency improvement of 1.1% annually to 2050[26].

Building Energy Use Calculations

Energy use is calculated separately for residential and commercial buildings, and new and existing building stock. The following sections describe in steps how energy use for each segment of the building population is calculated.

Energy Use of Residential Buildings

Energy use totals for new and existing residential buildings are first calculated separately, then added together.

Base Year Residential Energy Use

Base year residential energy use for natural gas and electricity represents the baseline calibration of the model for these metrics. It captures the varying energy use from each residential category in the base year and is not influenced by policy factors. The equation for calculating base year residential energy use is as follows:

Equation 9-1: Total regional base year residential energy use of dwelling unit type T

$$E_{Tb} = \sum (DU_T * A_T)$$

Where:

$E_{Tb} = Total\ base\ year\ residential\ energy\ use\ of\ dwelling\ unit\ of\ type$

$DU_T = Base\ year\ number\ of\ dwelling\ units\ of\ dwelling\ unit\ of\ type\ T\ by\ parcel$

$A_T = Annual\ electricity\ or\ gas\ use\ per\ dwelling\ unit\ of\ type\ T, by\ climate\ zone$

Future Scenario: New residential units

The annual electricity or natural gas use of new residential units – including those built on greenfield land as well as those constructed through infill or redevelopment – are calculated via the following steps:

1. Numbers of new residential units by building type are summed up at the level of the 5.5-acre grid cell or parcel.

[26] Williams, J. H. (2011). The Technology Path to Deep Greenhouse Gas Emissions Cute by 2050: The Pivotal Role of Electricity. *Science*.

2. The numbers of housing units are multiplied by the per-unit baseline energy use factors corresponding to building type and the climate zone designation of the grid cells or parcels.
3. Totals by building type are summed, yielding total baseline energy use per grid cell or parcel.
4. The effective end-year reduction resulting from the application of the New Construction Efficiency assumptions is applied.
5. The effective end-year reduction resulting from the application of the Retrofit Efficiency assumptions for new buildings is applied to the number of new homes (built after the base year of the model) that are subsequently retrofitted.
6. Grid-cell or parcel totals are summed up at the scale of the scenario or other user-defined geography.

The resulting totals reflect annual energy used by new residential buildings, by building type. Note that UrbanFootprint currently calculates annual totals for an end-state year. Future versions of the model will estimate annual totals for each year in a scenario, from a base year to a final horizon year, to provide interim results as well as cumulative totals spanning an entire scenario horizon (e.g., total energy use from 2012 to 2050).

Future Scenario: Existing residential units

Existing residential units include those existing in the base year that are subsequently retrofitted or replaced by units of the same type, as well as those that remain unchanged. Buildings built to replace existing units lost through redevelopment count as new buildings. Annual electricity or natural gas use is calculated via the following steps:

7. Numbers of existing residential units by building type are summed up at the level of the grid cell or parcel.
8. The numbers of housing units are multiplied by the per-unit baseline energy use factors corresponding to building type, and the climate zone designation of the grid cells or parcels.
9. Totals by building type are summed, yielding total baseline energy use per grid cell or parcel.
10. The effective end-year reduction resulting from the application of the Retrofit Efficiency assumptions for existing buildings is applied to the number of existing homes that are retrofitted.
11. The effective end-year reduction resulting from the application of the New Construction Efficiency assumptions to the segment of replaced existing buildings is applied.
12. Grid-cell or parcel totals are summed up at the scale of the scenario or other user-defined geography.

The resulting totals reflect annual energy used by existing buildings, by building type.

Equation 9-2: Total regional future-year annual residential energy use of dwelling unit of type T

$$E_{Tf} = \sum (E_{nT} + E_{nrT} + E_{rpT} + E_{rfT} + E_{ncT})$$

Where:

E_{Tf} = *Total future-year annual residential energy use of dwelling unit of type T*

E_{nT} = *Residential energy use (electricity or gas) in new non retrofit units of dwelling unit type T by parcel/grid*

$$E_{nT} = DU_{nT} * A_{rT} * (1 - C_{nr}) * (1 - R_n)$$

E_{nrT} = *Residential energy use (electricity or gas) in new retrofit units of dwelling unit type T by parcel/grid*

$$E_{nrT} = DU_{nT} * A_{rT} * C_{nr} * (1 - R_{nr})$$

E_{rpT} = *Residential energy use (electricity or gas) in replaced base units of dwelling unit type T by parcel/grid*

$$E_{rpT} = DU_{rT} * A_{rT} * C_{rp} * (1 - R_n)$$

E_{rfT} = *Residential energy use (electricity or gas) in retrofitted base units of dwelling unit type T by parcel/grid*

$$E_{rfT} = DU_{rT} * A_{rT} * C_{rf} * (1 - R_{rf})$$

E_{ncT} = *Residential energy use (electricity or gas) in no change base units of dwelling unit type T by parcel/grid*

$$E_{ncT} = DU_{rT} * A_{rT} * \left(1 - (C_{rp} + C_{rf})\right)$$

Where:

$DU_{nT} = Number\ of\ new\ dwelling\ units\ of\ type\ T$ *by parcel or grid*

$DU_{rT} = Remaining\ number\ of\ base\ year\ dwelling\ units\ of\ type\ T$ *by parcel or grid*

$A_{rT} = Annual\ electricity\ or\ gas\ use\ per\ dwelling\ unit\ of\ type\ T$

$C_{nr} = Percentage\ of\ new\ units\ that\ are\ retrofit\ in\ the\ time\ interval$

$C_{rp} = Percentage\ of\ persisting\ base\ year\ units\ that\ are\ replaced\ in\ the\ time\ interval$

$C_{rf} = Percentage\ of\ persisting\ base\ year\ units\ that\ are\ retrofit\ in\ the\ time\ interval$

$R_{nr} = Percent\ reduction\ in\ baseline\ energy\ use\ in\ new\ retrofit\ buildings$

$R_n = Percent\ reduction\ in\ baseline\ energy\ use\ in\ new\ buildings$

$R_{rf} = Percent\ reduction\ in\ baseline\ energy\ use\ in\ retrofit\ buildings$

Equation 9-3: Total regional residential base or future year energy use (electricity or natural gas)

$$E_{Tot} = E_{LL} + E_{SL} + E_{Att} + E_{MF}$$

Where

$E_{Tot} = Total\ regional\ energy\ use\ \ (electricity\ or\ gas)\ by\ all\ residential\ units$

$E_{LL} = Total\ energy\ use\ \ (electricity\ or\ gas)\ by\ Single\ Family\ Large\ Lot\ Units$

$E_{SL} = Total\ energy\ use\ \ (electricity\ or\ gas)\ by\ Single\ Family\ Small\ Lot\ Units$

$E_{ATT} = Total\ energy\ use\ \ (electricity\ or\ gas)\ by\ Attached\ Single\ Family\ Units$

$E_{MF} = Total\ energy\ use\ \ (electricity\ or\ gas)\ by\ Multifamily\ Units$

Energy Use of Commercial Buildings

Energy use totals for new and existing commercial buildings are first calculated separately, then added together.

Base Year Commercial Energy Use

Base year commercial energy use for natural gas and electricity represents the baseline calibration of the model. It captures the varying energy use from each commercial category in the base year and is not influenced by policy factors. The method for calculating base year commercial energy use is as follows:

Equation 9-4: Total regional base year commercial energy use of employment type T

$$E_{Tb} = \sum (B_T * E_{rT})$$

Where:

$E_{Tb} =\ Total\ base\ year\ commercial\ energy\ use\ of\ employment\ type\ T$

$B_T =\ Base\ Year\ building\ square\ feet\ of\ employment\ type\ T\ by\ parcel$

$E_{rT} =\ Annual\ electricity\ or\ gas\ use\ per\ square\ foot\ for\ employment\ type\ T\ by\ climate\ zone$

New commercial buildings

The annual electricity or natural gas use of new commercial buildings – including those built on greenfield land as well as those constructed through infill or redevelopment – are calculated via the following steps:

1. Amounts of commercial floor space by building type are summed up at the level of the grid cell or parcel.
2. Floor space totals are multiplied by the baseline energy intensities corresponding to building type, and the climate zone designation of the grid cells or parcels.

3. Grid-cell or parcel totals are summed up at the scale of the scenario or other user-defined geography.
4. The effective end-year reduction resulting from the application of the New Construction Efficiency assumptions is applied.
5. The effective end-year reduction resulting from the application of the Retrofit Efficiency assumptions for new buildings is applied to the amount of new floor space (built after the base year of the model) that is subsequently retrofitted.

The resulting totals reflect annual energy used by new commercial buildings, by building type.

Existing commercial buildings

Existing commercial buildings include those existing in the base year that are subsequently renovated, retrofitted, or replaced by units of the same type. Buildings built to replace existing units lost through redevelopment count as new buildings. Annual electricity or natural gas use is calculated via the following steps:

6. Amounts of commercial floor space by building type are summed up at the level of the grid cell (or parcel).
7. Floor space totals are multiplied by the baseline energy intensities corresponding to building type, and the climate zone designation of the grid cells (or parcels).
8. Grid-cell or parcel totals are summed up at the scale of the scenario or other user-defined geography.
9. The effective end-year reduction resulting from the application of the Renovation/Retrofit Efficiency assumptions for existing buildings is applied to the amount of existing floor space that is retrofitted.
10. The effective end-year reduction resulting from the application of the New Construction Efficiency assumptions to the segment of replaced existing buildings is applied.

The resulting totals reflect annual energy used by existing buildings, by building type. Note that UrbanFootprint currently calculates annual totals for an end-state year. Future versions of the model will estimate annual totals for each year in a scenario, from a base year to a final horizon year, to provide interim results as well as cumulative totals spanning an entire scenario horizon (e.g., total energy use from 2012 to 2050).

Equation 9-5: Total regional future-year commercial energy use of employment of type T

$$E_{Tf} = \sum (E_{nT} + E_{nrT} + E_{rpT} + E_{rfT} + E_{ncT})$$

Where:

E_{Tf} = *Total future-year annual commercial energy use of employment dwelling unit of type T*

$E_{nT} =$ *Commercial energy use (electricity or gas) in gross new non retrofit building square feet of employment type T by parcel/grid*

$$E_{nT} = B_{nT} * E_{rT} * (1 - C_{nr}) * (1 - R_n)$$

$E_{nT} =$ *Commercial energy use (electricity or gas) in gross new retrofit building square feet of employment type T by parcel/grid*

$$E_{nrT} = B_{nT} * E_{rT} * C_{nr} * (1 - R_{nr})$$

$E_{rpT} =$ *Commercial energy use (electricity or gas) in replaced/remodeled base building square feet of employment type T by parcel/grid*

$$E_{rpT} = B_{rT} * E_{rT} * C_{rp} * (1 - R_n)$$

$E_{rfT} =$ *Commercial energy use (electricity or gas) in retrofit base building square feet of employment type T by parcel/grid*

$$E_{rfT} = B_{rT} * E_{rT} * C_{rf} * (1 - R_{rf})$$

$E_{ncT} =$ *Commercial energy use (electricity or gas) in no change base building square feet of employment type T by parcel/grid*

$$E_{ncT} = B_{rT} * E_{rT} * \left(1 - (C_{rp} + C_{rf}\right))$$

Where:

$B_{nT} = Number\ of\ gross\ new\ building\ square\ feet\ of\ employment\ type\ T$ *by parcel or grid*

$B_{rT} = Remaining\ number\ of\ base\ year\ building\ square\ feet\ of\ employment\ type\ T$ *by parcel or grid*

$E_{rT} = CEUS\ annual\ electricity\ or\ gas\ use\ per\ square\ foot\ of\ employment\ type\ T$

$C_{nr} = Percentage\ of\ new\ commercial\ square\ footage\ that\ is\ retrofit\ in\ the\ time\ interval$

$C_{rp} = Percentage\ of\ persisting\ commercial\ base\ year\ square\ footage\ that\ is\ replaced\ in\ the\ time\ interval$

$C_{rf} = Percentage\ of\ persisting\ base\ year\ square\ footage\ that\ is\ retrofit\ in\ the\ time\ interval$

$R_n = Percent\ reduction\ in\ baseline\ energy\ use\ in\ new\ buildings$

$R_{nr} = Percent\ reduction\ in\ baseline\ energy\ use\ in\ new\ retrofit\ buildings$

$R_{rf} = Percent\ reduction\ in\ baseline\ energy\ use\ in\ retrofit\ buildings$

Equation 9-6: Total regional commercial base or future year energy use (electricity or natural gas)

$$E_{Tot} = E_{SO} + E_{LO} + E_{Med} + E_{FS} + E_{Ret} + E_{Ed} + E_{Oth} + E_{rcom} + E_{Wh} + E_{Ind}$$

Where

$E_{Tot} = Total\ regional\ energy\ use\ \ (electricity\ or\ gas)\ by\ all\ commercial\ buildings$

$E_{SO} = Total\ energy\ use\ \ (electricity\ or\ gas)\ by\ Small\ Office\ building\ square\ feet$

$E_{LO} = Total\ energy\ use\ \ (electricity\ or\ gas)\ by\ Large\ Office\ building\ square\ feet$

$E_{Med} = Total\ energy\ use\ \ (electricity\ or\ gas)\ by\ Medical\ Servies\ building\ square\ feet$

$E_{FS} = Total\ energy\ use\ \ (electricity\ or\ gas)\ by\ Food\ Service\ and\ Accomodation\ building\ square\ feet$

$E_{Ret} = Total\ energy\ use\ \ (electricity\ or\ gas)\ by\ Retail\ Services\ building\ square\ feet$

$E_{Ed} = Total\ energy\ use\ \ (electricity\ or\ gas)\ by\ Education\ Services\ building\ square\ feet$

$E_{Med} = Total\ energy\ use\ \ (electricity\ or\ gas)\ by\ Other\ Services\ building\ square\ feet$

$E_{FS} = Total\ energy\ use\ \ (electricity\ or\ gas)\ by\ Residential\ Commons\ building\ square\ feet$

$E_{Med} = Total\ energy\ use\ \ (electricity\ or\ gas)\ by\ Warehouses\ building\ square\ feet$

$E_{FS} = Total\ energy\ use\ \ (electricity\ or\ gas)\ by\ Manufacturing\ building\ square\ feet$

Building Energy Costs

Building energy costs include the retail costs for residential and commercial electricity and natural gas use. Costs are calculated as the product of energy use and user-defined projections for retail prices into the future.

Building Energy Cost Factors

Retail price factors are expressed as dollars per kilowatt-hour of electricity and therm of natural gas, with different prices assumed for residential and commercial energy. Base-year energy prices and emissions rates are derived from existing data, while future-year prices are dependent upon policy-based assumptions.

Note that the model expresses cost metrics in constant dollars, such that future-year prices are expressed in terms of today's dollars (for example, projected utility costs in the year 2050 are expressed in 2012 dollars).

Policy Basis for Assumptions

Electricity costs are expected to increase over time. The default per-kWh price projections are related to the percentage of renewables in the electricity generation portfolio. A relationship between price and portfolio mix was extrapolated from cost projections done as part of an analysis of the 33% Renewables Portfolio Standard conducted by the California Public Utilities Commission (CPUC)[27]. Though rough by virtue of the uncertainties involved, the resulting estimates are intended to be more representative of future conditions than a simple extrapolation of historical price trends. (Based generally on historical price trends, the CEC's retail electricity price projections to 2018 can be considered conservative[28].) Alternative assumptions can be tested to account for different factors that affect the price of electricity, such as the cost of electricity generation resources, various infrastructure costs, supply and demand, and potential regulations.

Natural gas costs are also expected to increase over time. The default per-therm price assumptions are based on historical retail price data to 2010 for California, as published by the Energy Information Administration (EIA)[29]. UrbanFootprint assumes that prices for all years beyond 2010 follow a simple trend based on price changes from 2000 to 2010. Alternative assumptions can be tested to account for different factors that affect the price of natural gas, such as the cost of natural gas resources, various infrastructure costs, supply and demand, and potential regulations. As for all assumptions, energy prices can be defined at any scale for which data is available and localized output is desired.

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[27] California Public Utilities Commission. (2009). *33% Renewables Portfolio Standard Implementation Analysis Preliminary Results*. Sacramento: CPUC.

[28] As stated by the CEC in the 2007 Integrated Energy Policy Report: "Most retail price forecasts are simply current rate structures projected out over time and applied to forecasted changes in operating costs. The process of developing the *2007 IEPR* retail price projection experienced the same over-simplification that plagued the 2003 and 2005 IEPR cycles. Although virtually all utility submittals to the Energy Commission call for real retail prices to fall, these forecasts do not consider the cost of infrastructure improvements and are based on extremely optimistic assumptions about the price of natural gas." (California Energy Commission. (2007). *Integrated Energy Policy Report*. Sacramento: CEC)

[29] U.S. Energy Information Administration. (2012). *California Gasoline and Diesel Prices*. Washington, D.C.: EIA.

Building Energy Cost Calculations

All building energy cost figures are products of electricity or natural gas use and price. Annual costs are calculated as shown in Equation 9-7.

Equation 9-7: Annual electricity or natural gas cost

$$D_{\mathrm{x}} = E_x * P_x$$

where:

D_x	=	Total annual cost (dollars) for electricity or gas used by all units built up to year x (e.g., annual use in 2035 for all units built between 2020 and 2035)
E_x	=	Electricity or gas used for all units built up to year x
P_x	=	Price per kilowatt-hour or therm in year x
x	=	Any year

Total annual energy cost is calculated as the sum of electricity and gas costs.

Building Energy Greenhouse Gas Emissions

UrbanFootprint calculates greenhouse gas (GHG) emissions associated with building energy use as a function of energy use and GHG emission rates for electricity generation and natural gas combustion. Emissions results vary according to the energy use profile of each scenario, and assumptions about the resource mix of the future energy portfolio.

Energy Emissions Rates

Emissions rates are expressed in terms of carbon dioxide equivalent (CO_2e) per kilowatt-hour of electricity and therm of natural gas. Electricity emissions rates can be linked to specific assumptions about changes in the electricity generation portfolio into the future. Natural gas emissions rates, which result from direct on-site use (e.g., via gas stoves), are assumed to remain stable over time.

Emissions from Electricity Use

CO_2e emissions are measured per unit of electricity consumed (pounds per megawatt-hour). The total emissions rate reflects combined emissions from conventional sources (coal, large hydroelectric, natural gas, and nuclear), and renewable sources (biomass, geothermal, small hydroelectric, solar photovoltaic, solar thermal, and wind) within the state's electricity generation portfolio.

To correspond with residential and commercial building energy emissions as determined by the California Air Resources Board GHG Inventory, UrbanFootprint uses a baseline CO_2e emission rate derived by dividing California's total emissions attributed to electric power generation in 2005[30] by total

[30] Total 2005 emissions from electric power generation as published in California Greenhouse Gas Inventory for 2000-2006. (California Air Resources Board. (2009). *California's Greenhouse Gas Emissions Inventory for 2000-2006, by Category as Defined in the Scoping Plan*. CARB: Sacramento.)

electricity consumption in that year[31]. The resulting rate of 812 lbs/MWh accounts for in-state as well as imported electricity, which comprises roughly 30% of California's electricity supply[32].

The EPA Emissions & Generation Resource Integrated Database (eGRID2012) is a comprehensive source for energy emissions data. Calculated for 26 subregions across the country, the eGRID emissions rates are recommended for use in developing carbon footprints or emission inventories. Based on comprehensive power plant-level data, the eGRID rates reflect total plant emissions for each unit of energy generated. Emissions from renewable sources are considered to be zero, as eGRID does not account for lifecycle (upstream) emissions. Methane (CH_4) and nitrous oxide (N_2O) rates are multiplied by their global warming potential (GWP) factors[33] and added to the CO_2 rate to arrive at a CO_2e emission rate.

Future electricity emissions rates are calculated based on projected resource mix, including in-state and imported electricity. Current average emission rates by resource type are shown in Table 9-6; emissions from renewable sources are not counted by eGRID.

Table 9-6: California CO_2e Emission Rates by Resource Type (eGRID)

Resource	Current CO_2 emissions (lbs/MWh)
Coal	2315 lbs/MWh
Oil	2260 lbs/MWh
Natural gas	980 lbs/MWh
Other fossil fuels	1040 lbs/MWh
Nuclear	-
Hydro	-
Biomass	-
Wind	-
Solar	-
Geothermal	-

Policy Basis for Assumptions

For California, GHG emission rates for electricity will decrease as the state's resource mix shifts to include a greater proportion of renewable sources. Like for building energy consumption, the proposed framework of default assumptions summarized in Table 9-7 represents three distinct policy directions: business-as-usual (BAU) performance, adopted policy, and aspirational policy.

[31] California Energy Commission. (2007). *California Energy Demand 2008-2018 Staff Revised Forecast*. Sacramento: CEC.

[32] California Energy Commission. (2008). *Net System Power Report*. Sacramento: CEC.

[33] Intergovernmental Panel on Climate Change. (2007). *Fourth Assessment Report*. Geneva: IPCC.

Table 9-7: Building Energy Emissions Assumptions

		BAU	Adopted	Aspirational
Greenhouse Gas Emissions Rates				
Residential & commercial building electricity emissions (lbs CO2e/kWh)	Baseline	0.81 lbs/kWh	0.81 lbs/kWh	0.81 lbs/kWh
	2020	0.81 lbs/kWh	0.61 lbs/kWh	0.61 lbs/kWh
	2035	0.81 lbs/kWh	0.61 lbs/kWh	0.43 lbs/kWh
	2050	0.81 lbs/kWh	0.61 lbs/kWh	0.056 lbs/kWh
Residential & commercial building natural gas emissions (lbs CO2e/therm)	Baseline	11.7 lbs/thm	11.7 lbs/thm	11.7 lbs/thm
	2020	11.7 lbs/thm	11.7 lbs/thm	11.7 lbs/thm
	2035	11.7 lbs/thm	11.7 lbs/thm	11.7 lbs/thm
	2050	11.7 lbs/thm	11.7 lbs/thm	11.7 lbs/thm

The BAU policy set is defined primarily for demonstration purposes, enabling a baseline comparison among scenarios. The Adopted policy set is intended to reflect currently adopted policy, with limited improvement occurring thereafter. Lastly, the Aspirational policy set reflects policies geared toward meeting California's AB32 Greenhouse Gas reduction goal of reducing emissions to 80% below 1990 levels by 2050. In terms of building energy emissions, the policy sets are defined as follows:

- The BAU policy set assumes that no improvements are made in the electricity generation portfolio to 2050, such that the emissions rate remains constant to 2050. This allows for a 'clean' policy-neutral analysis of the role of land use and transportation systems in scenarios without the impact of other policies.

- The Adopted policy set is based on a projected resource mix that meets the California Renewables Portfolio Standard (RPS) goal of 33% renewable sources by 2020, and remains unchanged thereafter. The assumed mix is 33% renewables, 29% natural gas, 16% large hydro, 12% nuclear, and 10% coal. Emissions from on-site natural gas combustion are assumed to remain constant at the CPUC-approved baseline rate, which already represents a high level of efficiency.

- The Aspirational policy set assumes attainment of a much higher proportion of renewables. By 2020, the RPS goal for 33% renewables is met. By 2050, the statewide electricity generation portfolio is assumed to include 74% renewables[34]. The emissions rate is based on a portfolio composed of 74% renewables, 16% large hydro, 6% nuclear, and 4% natural gas. Emissions from on-site natural gas combustion are assumed to remain constant to 2050.

[34] Maximum renewables potential estimated by Energy and Environmental Economics (E3) in their assessment of the energy policies and advancements required to meet California's GHG reduction goals. (Energy and Environmental Economics, Inc. (2009). *Meeting California's Long-Term Greenhouse Gas Reduction Goals*. San Francisco: Energy and Environmental Economics, Inc.)

CHAPTER 10
Water Impacts

UrbanFootprint models residential and commercial water uses for all buildings in a base year and for future scenarios. Scenarios vary in their water use profiles due to their building program, the location of new growth, and policy-based assumptions about improvements in water efficiency over time. The costs and greenhouse gas (GHG) emissions associated with water use, in turn, vary according to policy-based price and emissions rate assumptions. This section details the methodology and assumptions used to model water use and its related impacts.

Water Use

Indoor and outdoor water use for residential and commercial buildings is modeled separately within UrbanFootprint. Indoor water use is estimated on a per-capita basis, while outdoor water use is estimated on the basis of irrigated area at the parcel scale. Indoor and outdoor water use is first calculated according to baseline rates and then adjusted to account for the application of efficiency and conservation policies into the future.

Baseline Water Use

This section outlines the basis for the model's baseline water use factors, which quantify residential indoor water use per capita by building type, commercial indoor water use per capita by employment category, and outdoor water use per irrigated square foot by climate zone. Building types are tied to scenario composition, while climate zone is location-dependent.

Indoor Residential Water Use Factors

Indoor water use varies according to household size and building type, with multifamily homes generally requiring slightly less water per capita than single family homes. Baseline indoor water use factors are expressed in terms of gallons per capita per day (gpcd). Indoor usage patterns generally do not vary significantly by climate or location (if the same building/fixture standards are in place). However, indoor factors can be calibrated to regional or local data where available. Table 10-1 shows the schema of the California indoor residential water use baseline factors used by UrbanFootprint.

Table 10-1: Indoor Residential Water Use by Building Type (gallons per capita per day)

Residential Building Type	Gallons/capita/day
Single Family Detached	70
Single Family Attached	60
Multifamily	60

Indoor Commercial Water Use Factors

Indoor water use for commercial uses (which within UrbanFootprint includes institutional and industrial uses) is estimated on a per-employee basis. This approach is based on existing research and data that estimates commercial, institutional, and industrial water use in terms of gallons per employee per day (GED) by employment sector[35]. These factors were derived from a combination of modeled and survey data, taking into account general water uses, such as building cooling and restroom use, as well as water uses that relate to specific employment sectors, such as food service or medical care. Because UrbanFootprint models outdoor water use separately from indoor water use, the landscape irrigation component of per-employee water use rates is excluded.

The current version of the model uses baseline per-employee indoor water use factors for three general categories: retail, office, and industrial. These factors represent average use across all NAICS subsectors within each commercial category. These rates are applied to the numbers of jobs by category in each scenario, which is determined by base year data and allocations of future employment as specified by place and building types.

Baseline Outdoor Water Use Factors

Outdoor water use for residential and commercial buildings is calculated based on assumptions about amount of irrigated area, and per-acre watering needs based on climate. The irrigated acreage per residential unit, or per acre of a commercial building type, is estimated using lot size, impervious cover, and irrigated land percentage assumptions.

Reference Evapotranspiration Values

Per-acre landscape irrigation requirements are derived from reference evapotranspiration (ETo) values. Evapotranspiration values, which measure plant water loss to the atmosphere, vary according to climate. The California Department of Water Resources provides monthly and yearly average ETo values for 18 zones in the state[36], as shown in Figure 10-1. These values, expressed in inches of water, are used to determine per-acre outdoor water demand per month or year. An evapotranspiration adjustment factor is applied as a multiplier to evapotranspiration values to reflect assumptions about plant types and irrigation efficiency. This method for estimating outdoor water demand is detailed by the California Department of Water Resources' Model Water Efficient Landscape Ordinance[37]. UrbanFootprint uses annual ETo values.

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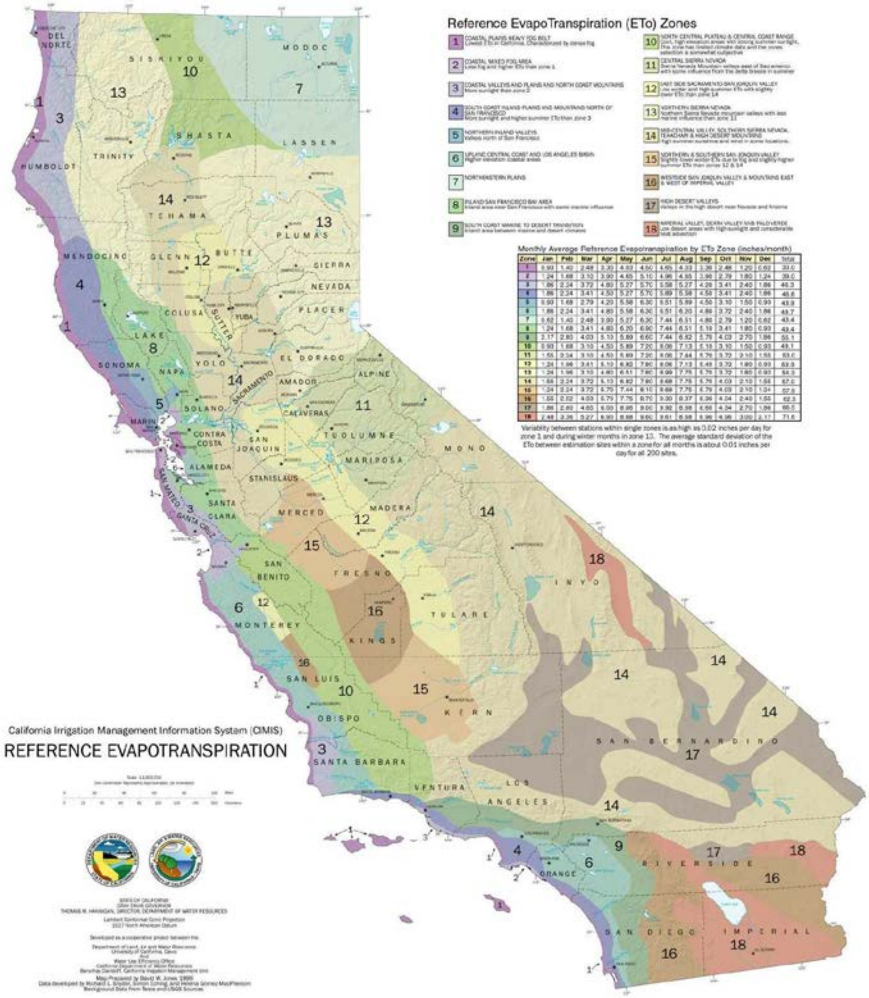
[35]Factors based on studies published by the Pacific Institute and others, which have yielded estimates for water use classified by standard industrial classification (SIC) code (Dziegielewski et al. 2000 as published in Pacific Institute, 2003). Factors are expressed in gallons per employee per day, assuming a 365-day year. In most cases, the factors are converted from data expressed in gallons per employee day for other numbers of days per year (for example, a 225-day year that accounts for work days only).

[36] California Irrigation Management Information System, 1999. *Reference Evapotranspiration Zones*. Available at http://wwwcimis.water.ca.gov/cimis/infoEtoOverview.jsp;jsessionid=A3B1A8C8273FBC7E74297B5C0710244D.

[37] CA Department of Water Resources, 2009. *Model Water Efficient Landscape Ordinance*. Available at http://www.water.ca.gov/wateruseefficiency/landscapeordinance/.

Figure 10-1: California Irrigation Management System Reference Evapotranspiration Zones



Residential Outdoor Irrigated Area Assumptions

The amount of outdoor irrigated area per residential unit varies according to assumptions about lot size, hardscape percentage, and irrigated percentage. Assumptions for hardscape percentage and irrigated percentage are grounded in building type studies, which incorporate estimates related to building footprint as well as analysis of aerial imagery. For multifamily units, an estimate of shared outdoor area per unit is used. Equation 10-1 shows how the factors for average irrigated area by building type, are calculated. These factors are subsequently used in the residential outdoor water use calculations.

Equation 10-1: Residential Outdoor Irrigated Area

$$A_{iT} = A_T * (1 - H_T) * I_T$$

where:

$A_{iT} = Irrigated\ area\ for\ a\ lot\ of\ building\ type\ T$

$A_T = Area\ of\ residential\ lot\ for\ building\ type\ T$

$H_T = Percentage\ of\ lot\ for\ residential\ building\ type\ T\ that\ is\ hardscape$

$I_T = Percentage\ of\ softscape\ area\ of\ building\ type\ T\ lot\ that\ is\ irrigated$

Table 10-2 summarizes these factors, showing the assumptions used to estimate them.

Table 10-2: Residential Outdoor Irrigated Area Assumptions by Building Type

Building Type	Average residential lot size or outdoor area per multifamily unit (sqft)	Impervious/ hardscape % (assumption)	Softscape % (100% - Impervious %)	Irrigated % (assumption)	Irrigated area per unit (softscape area * irrigated %)	Residential irrigated area per unit (sqft)
Skyscraper Mixed Use	180 sqft	99%	1%	62%	1%	0 sqft
High-Rise Mixed Use	210 sqft	86%	14%	45%	6%	15 sqft
Mid-Rise Mixed Use	280 sqft	98%	2%	50%	1%	5 sqft
Low-Rise Mixed Use	360 sqft	91%	9%	35%	3%	10 sqft
Main Street Commercial/MU High	520 sqft	92%	9%	50%	4%	20 sqft
Main Street Commercial/MU Low	1,120 sqft	100%	1%	60%	0%	5 sqft
Skyscraper Residential	80 sqft	37%	63%	15%	10%	10 sqft
High-Rise Residential	120 sqft	64%	36%	34%	12%	15 sqft
Urban Mid-Rise Residential	310 sqft	85%	15%	41%	6%	20 sqft
Urban Podium Multi-Family	420 sqft	75%	25%	41%	10%	40 sqft
Standard Podium Multi-Family	710 sqft	66%	34%	27%	9%	65 sqft
Suburban Multifamily Apt/Condo	1,050 sqft	80%	20%	50%	10%	105 sqft
Urban Townhome/Live-Work	1,810 sqft	53%	47%	25%	12%	210 sqft
Standard Townhome	2,270 sqft	80%	20%	50%	10%	225 sqft
Garden Apartment	1,770 sqft	50%	50%	50%	25%	440 sqft
Very Small Lot 3000	2,820 sqft	70%	30%	50%	15%	425 sqft
Small Lot 4000	4,250 sqft	65%	35%	50%	18%	745 sqft
Medium Lot 5500	5,560 sqft	58%	42%	50%	21%	1,170 sqft
Large Lot 7500	7,860 sqft	40%	60%	50%	30%	2,360 sqft
Estate Lot	13,240 sqft	25%	75%	50%	37%	4,935 sqft
Rural Residential	84,440 sqft	5%	95%	8%	8%	6,415 sqft
Rural Ranchette	283,680 sqft	2%	98%	4%	4%	10,000 sqft[38]

Commercial Outdoor Irrigated Area Assumptions

Total outdoor commercial water use varies by scenario due to differences in built form, as determined by the buildings types used to accommodate employment growth. The outdoor irrigated area factors for commercial buildings are expressed as a proportion of net parcel acre of development by building type. Irrigated area per net acre of development is estimated according to building type parameters that describe built form, including floor-area ratio (FAR) and building height to determine building footprint, combined with assumptions about how much of the remaining area is irrigated. The allocation of residential versus commercial uses also comes into play for mixed-use building types, with outdoor irrigated area apportioned to residential and commercial uses according to their respective proportions of building area. Equation 10-2 shows how the factors for average irrigated area by building type are calculated.

Equation 10-2: Commercial Outdoor Irrigated Area

$$A_{iT} = A_T * (1 - H_T) * I_T$$

[38] This is an assumed maximum for Rural Ranchettes.

where:

$A_{iT} = Irrigated\ area\ of\ commercial\ lot\ for\ building\ type\ T$

$A_T = Area\ of\ commercial\ lot\ for\ building\ type\ T$

$H_T = Percentage\ of\ lot\ for\ commercial\ building\ type\ T\ that\ is\ hardscape$

$I_T = Percentage\ of\ softscape\ area\ of\ building\ type\ T\ lot\ that\ is\ irrigated$

Table 10-3 summarizes the resulting per-acre factors, showing the assumptions used to estimate them. The resulting factors are used in the calculations of residential outdoor water use.

Commercial water use among scenarios varies according to the variation in building types accommodating the same types and numbers of jobs. For instance, office buildings located in urban areas tend to have minimal outdoor irrigated area, and hence water needs, as compared with office buildings situated within suburban office parks.

Table 10-3: Commercial Outdoor Irrigated Area Assumptions by Building Type

Building Type	Total hardscape %	Softscape %	Irrigated % of softscape	Irrigated % of acre	Commercial irrigated area per acre of building type (square feet)
Mixed Use					
Skyscraper Mixed Use	99%	1%	62%	1%	140 sf
High-Rise Mixed Use	86%	14%	45%	6%	1,115 sf
Mid-Rise Mixed Use	98%	2%	50%	1%	120 sf
Low-Rise Mixed Use	91%	9%	35%	3%	260 sf
Parking Structure/Mixed Use	32%	68%	30%	21%	4,470 sf
Main Street Commercial/MU High	92%	9%	50%	4%	795 sf
Main Street Commercial/MU Low	100%	1%	60%	0%	65 sf
Commercial					
Skyscraper Office	52%	48%	46%	22%	9,620 sf
High-Rise Office	63%	37%	44%	16%	7,020 sf
Mid-Rise Office	42%	58%	28%	16%	7,115 sf
Low-Rise Office	56%	44%	38%	17%	7,360 sf
Main Street Commercial (Retail + Office/Medical)	75%	25%	36%	9%	3,920 sf
Parking Structure+Ground-Floor Retail	100%	0%	50%	0%	0 sf
Parking Structure	93%	7%	50%	3%	1,430 sf
Office Park High	78%	22%	50%	11%	4,775 sf
Office Park Low	85%	15%	50%	8%	3,265 sf
Industrial High	100%	0%	50%	0%	0 sf
Industrial Low	100%	0%	50%	0%	0 sf
Warehouse High	85%	15%	15%	2%	980 sf
Warehouse Low	85%	15%	15%	2%	980 sf
Hotel High	85%	15%	50%	8%	735 sf
Hotel Low	85%	15%	50%	8%	165 sf
Regional Mall	85%	15%	50%	8%	3,265 sf
Medium Intensity Strip Commercial	85%	15%	50%	7%	3,085 sf
Low Intensity Strip Commercial	85%	15%	50%	7%	3,265 sf

Building Type	Total hardscape %	Softscape %	Irrigated % of softscape	Irrigated % of acre	Commercial irrigated area per acre of building type (square feet)
Rural Employment	0%	100%	85%	85%	36,615 sf
Institutional					
Campus/College High	85%	15%	90%	14%	5,880 sf
Campus/College Low	85%	15%	90%	14%	5,880 sf
Hospital/Civic/Other Institutional	85%	15%	90%	14%	5,880 sf
Civic					
Urban Elementary School	85%	15%	90%	14%	5,880 sf
Non-Urban Elementary School	85%	15%	90%	14%	5,880 sf
Urban Middle School	85%	15%	90%	14%	5,880 sf
Non-Urban Middle School	85%	15%	90%	14%	5,880 sf
Urban High School	85%	15%	90%	14%	5,880 sf
Non-Urban High School	85%	15%	90%	14%	5,880 sf
Urban City Hall	85%	15%	50%	8%	3,265 sf
Urban Convention Center	85%	15%	50%	8%	3,265 sf
Suburban Civic Complex	85%	15%	50%	8%	3,265 sf
Town Civic Complex	85%	15%	50%	8%	3,265 sf

Water Efficiency Policy Options

Policies for water efficiency and conservation are a major determinant of water use. This section describes the framework of assumptions applied by UrbanFootprint to reflect the impact of changing policies into the future. New buildings are expected to meet increasingly higher standards for new construction, while the population of existing buildings is expected to exhibit improved performance as a result of buildings and landscaped areas being retrofitted or replaced.

Building Stock Categorization

The stock of residential and commercial buildings is subject to ongoing changes, as new construction, retrofits, renovations, and demolition occur. UrbanFootprint tracks the amounts of residential units and employees in each of these building populations. The numbers of buildings that are built or lost (through redevelopment) result from the application of place types, with their component building types, to the landscape. The numbers of buildings that are either retrofit or replaced are determined by assumed annual rates compounded to the scenario interval, which can be varied to reflect the effects of policies that incentivize efficiency improvements for existing buildings. Finally, some amount of buildings – the remainder – can be assumed not to change.

Going forward, each segment of the building population is subject to differing rates of improvement, as specified by assumed water efficiency factors. Specific policy options for use in California are outlined following the description of the efficiency factors.

Water Efficiency Factors

Three different types of water use reduction factors are applied to express the effects of policy implementation on the various populations of new and existing buildings: 1) new construction efficiency, which is applied to reflect the implementation of higher efficiency standards and policies into the future; 2) retrofit efficiency, which is applied to reflect water savings due to building improvements; and 3) ongoing efficiency improvement, which is applied to reflect continued improvement due to efficiency and conservation measures.

New Construction Efficiency

New construction includes new buildings and wholesale replacement and major renovations. This includes buildings built on greenfield land, those constructed through infill or redevelopment, and those built as replacements of existing buildings – each of these categories are treated as new construction. The “new construction efficiency” factor can be set to reflect specific water-saving policies for new construction, such as California’s Title 24 building standards, as well as local green building codes. The factor is expressed as a set of horizon-year energy use reduction targets (e.g., for 2020, 2035, and 2050) from baseline water use. Different sets of targets can be applied to test specific policies for residential and commercial water use, and their indoor and outdoor components.

Between horizon-year targets, the reductions are assumed to deepen at a steady rate. Thus, a multifamily unit built in 2025 would use less water per year than the same type of unit built in 2015 – a rate which persists thereafter. By default, growth is assumed to occur at a steady rate between horizon years – that is, an equal number of units are allocated to each year over a defined period, though assumptions about the pace of new growth can be varied.

Within UrbanFootprint, a spreadsheet-based module is used to project forward the effects of deepening reductions over time to an end-state year – or in other words, convert horizon-year reduction targets into effective end-state reductions. Table 10-4 shows a sample of this conversion (populated with demonstration values), in which a policy for new construction efficiency meets a 20% reduction by 2020, a 50% reduction by 2035, and an 80% reduction by 2050. The resulting rate, to be applied to all homes constructed over the period 2010 to 2050, is 41%.[39]

[39] Future versions of UrbanFootprint will incorporate functionality to calculate annual metrics for each year between a scenario base year and end-state year, enabling interim-year and cumulative total results reporting.

Table 10-4: Conversion of horizon-year target reductions to effective end-state reductions

Year	Water efficiency factor – (Target reduction INPUT)	New Units built in year	Total Units	Baseline water use per unit	Efficient water use per unit (water reduction applied)	Vintage totals – total water used by buildings constructed within one year	Annual total – total water used by buildings of all ages	Average water use per unit	Effective end-year efficiency reduction
2010	0%	0	0	100 gal	100 gal	0 gal	0 gal	0 gal	0%
2011	2%	2,500	2,500	100 gal	98 gal	245,000 gal	245,000 gal	98 gal	-2%
2012	4%	2,500	5,000	100 gal	96 gal	240,000 gal	485,000 gal	97 gal	-3%
2013	6%	2,500	7,500	100 gal	94 gal	235,000 gal	720,000 gal	96 gal	-4%
2014	8%	2,500	10,000	100 gal	92 gal	230,000 gal	950,000 gal	95 gal	-5%
2015	10%	2,500	12,500	100 gal	90 gal	225,000 gal	1,175,000 gal	94 gal	-6%
2016	12%	2,500	15,000	100 gal	88 gal	220,000 gal	1,395,000 gal	93 gal	-7%
2017	14%	2,500	17,500	100 gal	86 gal	215,000 gal	1,610,000 gal	92 gal	-8%
2018	16%	2,500	20,000	100 gal	84 gal	210,000 gal	1,820,000 gal	91 gal	-9%
2019	18%	2,500	22,500	100 gal	82 gal	205,000 gal	2,025,000 gal	90 gal	-10%
2020	20%	2,500	25,000	100 gal	80 gal	200,000 gal	2,225,000 gal	89 gal	**-11%**
2021	22%	2,500	27,500	100 gal	78 gal	195,000 gal	2,420,000 gal	88 gal	-12%
⋮									
2034	48%	2,500	60,000	100 gal	52 gal	130,000 gal	4,500,000 gal	75 gal	-25%
2035	50%	2,500	62,500	100 gal	50 gal	125,000 gal	4,625,000 gal	74 gal	**-26%**
2036	52%	2,500	65,000	100 gal	48 gal	120,000 gal	4,745,000 gal	73 gal	-27%
⋮									
2049	78%	2,500	97,500	100 gal	22 gal	55,000 gal	5,850,000 gal	60 gal	-40%
2050	80%	2,500	100,000	100 gal	20 gal	50,000 gal	5,900,000 gal	59 gal	**-41%**

Retrofit Efficiency

Water use in the population of existing buildings can be expected to decline over time as a result of buildings being retrofitted with new systems, fixtures, and irrigation technologies. Similarly, water use in the population of "new" buildings (those built within the time span of a scenario) can be expected to be further reduced due to retrofits in the years subsequent to their construction. The number of homes, or commercial buildings, that undergo retrofits are determined by a retrofit rate assumption, taken as a percentage of building stock in each year. (This retrofit rate is also used in building energy use calculations.)

The model uses a "retrofit efficiency" factor to reflect the savings potentials for residential and commercial indoor and outdoor water use. This factor is expressed in terms of horizon-year target reductions from baseline (in the same way that the new construction efficiency factor is expressed). The resulting end-year reductions are applied to the numbers of new and existing buildings that are assumed to be retrofitted over time.

Ongoing Conservation

To account for water use reductions resulting from continued minor improvements and conservation behaviors, the model applies an additional Upgrade Efficiency factor to all buildings. A percentage reduction is applied as an annual reduction from the annual energy use total of the replacement units of the base. Over time, a rate of 0.25% would compound such that units can achieve a maximum of about 11% in additional energy savings to 2050.

Policy Basis for Assumptions

Table 10-5 shows a proposed framework of default water efficiency assumptions for California that represent three distinct policy directions: business-as-usual (BAU) performance, adopted policy, and aspirational policy. End-state targets are linked to specific years. Water use in interim years is calculated according to a straight-line trend between the targets.

Table 10-5: Building Water Efficiency and Turnover Assumptions

	Target Year	BAU	Adopted	Aspirational
Residential Buildings				
New/Redeveloped/Replaced Residential Construction Water Efficiency (% reduction from baseline)	2020 2035 2050	0% 0% 0%	-35% -35% -35%	-35% -50% -70%
Residential Retrofit Efficiency (% reduction from baseline)	2020 2035 2050	0% 0% 0%	-22% -25% -30%	-22% -40% -50%
Percent of base/existing residential buildings retrofitted each year	All years	1.0%	1.0%	1.0%
Percent of base/existing residential buildings replaced each year (EXCLUDING redevelopment	All years	0.6%	0.6%	0.6%
Percent of new residential buildings that are subsequently retrofitted	All years	0.6%	0.6%	0.6%
Commercial Buildings				
New/Redeveloped/Replaced Commercial Construction Efficiency (% reduction from baseline)	2020 2035 2050	0% 0% 0%	-35% -35% -35%	-35% -50% -70%
Commercial Retrofit Efficiency (% reduction from baseline)	2020 2035 2050	0% 0% 0%	-22% -25% -30%	-22% -40% -50%
Percent of base/existing commercial floor space retrofitted each year	All years	0.95%	0.95%	0.95%
Percent of base/existing commercial floor space replaced each year (EXCLUDING redevelopment)	All years	1.0%	1.0%	1.0%
Percent of new commercial buildings that are subsequently retrofitted	All years	0.6%	0.6%	0.6%

The BAU policy set is defined primarily for demonstration purposes, enabling a baseline comparison among scenarios. The Adopted policy set is intended to reflect currently adopted policy, with limited improvement occurring thereafter. Lastly, the Aspirational policy set reflects policies geared toward achieving maximum potential savings. In terms of water use, the policy sets are defined as follows:

- The BAU policy set assumes that no improvements are made in building water efficiency to 2050. This allows for a 'clean' policy-neutral analysis of the role of land use and transportation systems in scenarios without the impact of other policies.

- The Adopted policy set assumes that new homes ramp down to using 35% less water than baselines by 2050, while existing homes use 30% less, due to building energy efficiency policies for new construction, retrofits, and replacements/major renovations. The commercial water use assumptions align with the residential assumptions, with new commercial buildings also ramping down to 35% below baseline by 2050, and existing buildings using 30% less. This combination of policy assumptions is geared toward achieving a 20% reduction in gallons per capita per day (gpcd) by 2020, in line with the California "20 by 20" urban water use reduction target[40], with modest improvement thereafter.

- The Aspirational policy set assumes that new homes use 70% less water than baselines by 2050, and existing homes use 50% less, due to policies for water efficiency and conservation. The commercial water use assumptions align with the residential assumptions, with buildings achieving the same percentage reductions. This combination of policy assumptions is geared toward achieving a 50% reduction in gallons per capita per day, in line with the California Department of Water Resources (DWR) Urban Water Management Plan goals of achieving 100 gpcd from a current 198 gpcd average[41].

Water Use Calculations

Water use is calculated separately for residential and commercial buildings, and new and existing building stock. The following sections describe in steps how water use for each segment of the building population is calculated.

In UrbanFootprint, water use methodology is different depending on whether water consumption is being modeled for the base year or a future scenario. Future scenario calculations make use of a number of policy-dependent factors which can be changed in order to influence water consumption in the future. Base-year calculations assume a baseline consumption pattern and do not make use of policy factors. Indoor and outdoor water use is calculated separately in order to incorporate geographic, environmental and policy-level influences on water consumption in base and future years.

Residential Indoor Water Use: Base Year

The annual residential base year indoor water use is calculated using the per-capita water use associated with residential dwelling unit types. In UrbanFootprint, these types are Single Family and

[40] Senate Bill X7-7. Documentation available at www.water.ca.gov/wateruseefficiency/sb7/

[41] CA Department of Water Resources, 2012. *Urban Water Management Plan*. Available at www.water.ca.gov/urbanwatermanagement/docs/Report%20to%20Leg%20on2010%20UWMPs-6-25-2012.pdf

Multifamily dwelling units. Population is modeled from dwelling unit counts at the parcel (or grid-cell) scale from which indoor water consumption is modeled. It is modeled in these steps:

1. Single family population is modeled at the parcel scale using the occupancy rate at the parcel scale and the household average size at the parcel scale derived from census attributes.
2. Multifamily population is modeled at the parcel scale using the occupancy rate at the parcel scale and the household average size at the parcel scale derived from census attributes.
3. For each, single family and multifamily population, the associated gallons per capita per day factor is applied to the population at the parcel scale and multiplied by the annualization factor to derive annual indoor water use in gallons for single family and multifamily units.
4. Single family and multifamily indoor water use are added together at the parcel scale and then summed to the region.

Steps 1 -3 Equation: Total regional base year residential indoor water use of dwelling unit type T for all parcels

$$Wi_T = \sum (DU_T * O_R * H_s * \ W_T * A_r)$$

Where:

$Wi_T = Total\ regional\ indoor\ water\ use\ for\ dwelling\ unit\ type\ T\ for\ all\ parcels$

$DU_T = \ Base\ Year\ number\ of\ dwelling\ units\ of\ dwelling\ unit\ of\ type\ T\ by\ parcel$

$O_R = \ Percent\ of\ dwelling\ units\ that\ are\ occupied$

$H_s = \ Number\ of\ people\ per\ household$

$W_T = \ Gallons\ of\ water\ use\ per\ person\ per\ day\ in\ dwelling\ unit\ type\ T$

$A_r = Annualization\ Factor$

$T = \ Single\ Family\ or\ Multifamily$

Step 4 Equation: Total regional base or future residential indoor water use for all parcels

$$Wi_r = \ Wi_{SF} + Wi_{MF}$$

Where

$Wi_r = Total\ regional\ residential\ water\ use\ for\ all\ parcels$

$Wi_{SF} = Total\ regional\ indoor\ water\ use\ by\ Single\ Family\ Units$

$Wi_{MF} = Total\ regional\ indoor\ water\ use\ by\ Multifamily\ Units$

Base Year Residential Outdoor Water Use

The annual residential base year outdoor water use is calculated using the irrigated area associated with each parcel in a region. Outdoor water use is dependent on this parcel-level attribute, the climate zone specific evapotranspiration rate and the irrigation efficiency rate. It is modeled in these steps:

1. Residential irrigated area is multiplied by the climate zone evapotranspiration rate and the residential irrigation efficiency rate.
2. Outdoor water use is then summed to the region to produce total base year outdoor water use in acre-feet.

Steps 1 and 2 Equation: Total regional base year residential outdoor water use for all parcels

$$Wo_r = \sum (I_R * E_R * Ef_r)$$

Where:

$Wo_r = Total\ regional\ residential\ outdoor\ water\ use\ for\ all\ parcels$

$I_R = Base\ year\ residential\ irrigated\ acres\ by\ parcel$

$E_R = Evapotranspiration\ rate\ per\ year\ (Acre\ feet)\ by\ climate\ zone$

$Ef_R = Regional\ residential\ irrigation\ efficiency\ factor$

Base Year Total Annual Residential Water Use

Total residential water use is the sum of annual residential indoor water use and the sum of annual residential outdoor water use. The equation is as follows:

Total annual residential water use in the base year for all parcels/grids

$$W_r = Wi_r + Wo_r$$

Where:

$W_r = Total\ annual\ residential\ water\ use$

$Wi_r = Total\ annual\ residential\ indoor\ water\ use$

$Wo_r = Total\ annual\ residential\ outdoor\ water\ use$

Residential Indoor Water Use: Future Year

Residential indoor water use in future scenarios is modeled in two parts. First, new residential indoor water use is modeled and secondly, persisting base year indoor water use is modeled. This allows for policy assumptions to interact with these populations separately.

Future Year New Residential Indoor Water Use

The annual indoor water use of new residential units – including those built on greenfield land as well as those constructed through infill or redevelopment – is calculated via the following steps:

1. The population by residential building type is calculated at the parcel or grid scale for single family and multifamily dwelling units.
2. These populations are then grouped into whether the dwelling units they were associated with were retrofit in the interval or if the dwellings maintained the water consumption reductions associated with the time they were built (non-retrofit).
4. For each retrofit and non-retrofit population total by building type, these are multiplied by the per-capita water use factors corresponding to each building type.
5. The non-retrofit reduction factor base on construction efficiency assumptions is applied to the non-retrofit population.
6. The retrofit reduction factor based on construction efficiency assumptions and further retrofits is applied to the retrofit population.
7. The retrofit and non-retrofit populations are summed together for each dwelling unit type at the parcel or grid cell scale.
8. Parcel or grid-cell scale single family and multifamily indoor water use are added together and summed to the scale of the scenario or other user-defined geography, yielding total indoor water use for new residential buildings.

Equations Steps 1 – 6:

Residential indoor water use in non-retrofit new units of dwelling unit type T by parcel/grid

$$Wi_{nrT} = DU_{nT} * O_R * H_s * (1 - C_{nr}) * W_T * (1 - R_n)$$

Residential indoor water use in retrofit new units of dwelling unit type T by parcel/grid

$$Wi_{rT} = DU_{nT} * O_R * H_s * C_{nr} * W_T * (1 - R_{nr})$$

Where:

$Wi_{nrT} = Residential\ indoor\ water\ use\ for\ non\ retrofit\ dwelling\ unit\ type\ T\ by\ parcel$

$Wi_{rT} = Residential\ indoor\ water\ use\ for\ retrofit\ dwelling\ unit\ type\ T\ by\ parcel$

$DU_{nT} = Number\ of\ new\ dwelling\ units\ of\ type\ T$ *by parcel*

$O_R = Percent\ of\ dwelling\ units\ that\ are\ occupied$

$H_s = \ Number\ of\ people\ per\ household$

$C_{nr} = \ Percentage\ of\ new\ units\ that\ are\ retrofit\ in\ the\ time\ interval$

$R_n = \ Percent\ reduction\ in\ baseline\ water\ use\ in\ \ new\ buildings$

$R_{nr} = \ Percent\ reduction\ in\ baseline\ water\ use\ in\ \ new\ buildings\ that\ are\ retrofit\ in\ the\ time\ interval$

$W_T = \ Gallons\ of\ water\ use\ per\ person\ per\ day\ in\ dwelling\ unit\ type\ T$

$T = \ Single\ Family\ or\ Multifamily$

Step 7 Equation: Future residential indoor water use by new residential units of type T by parcel/grid

$$Wi_T = \ Wi_{rT} \ + \ Wi_{nrT}$$

Where:

$Wi_T = Indoor\ water\ use\ for\ dwelling\ unit\ type\ T$

$Wi_{rT} = Indoor\ water\ use\ in\ retrofit\ new\ dwelling\ units\ of\ dwelling\ unit\ type\ T$

$Wi_{nrT} = \ Indoor\ water\ use\ in\ non\ retrofit\ new\ dwelling\ units\ of\ dwelling\ unit\ type\ T$

Step 8 Equation: Total regional future residential indoor water use on new residential units for all parcel/grids

$$Wi_n = \sum (Wi_{nSF} + Wi_{nMF})$$

Where

$Wi_n = Total\ residential\ indoor\ water\ use\ for\ new\ dwelling\ units\ for\ all\ parcels$

$Wi_{nSF} = Indoor\ water\ use\ by\ new\ Single\ Family\ Units\ at\ the\ parcel\ or\ grid\ scale$

$Wi_{nMF} = Indoor\ water\ use\ by\ new\ Multifamily\ Units\ at\ the\ parcel\ or\ grid\ scale$

Future Year Persisting Residential Indoor Water Use

The annual indoor water use of existing or “persisting” units in a future scenario – those existing in the base year that are subsequently retrofitted or replaced by units of the same type – is modeled in three parts: those that are replaced with the same type of unit in the interval; those that are retrofit with water efficiencies; and those that do not change in the interval. The annual outdoor water use of existing residential units is calculated via the following steps and equations:

1. The population by residential building type is calculated at the parcel or grid scale for single family and multifamily dwelling units.

2. The buildings associated with each parcel population are then divided into those that are replaced in the time interval with new standards, those that are retrofit with upgraded standards and those that do not change.
    a. For replaced dwelling units, the population is multiplied by the annual water use factor, and the water reduction associated with new buildings for both single family and multifamily dwelling units.
    b. For retrofit dwelling units, the population is multiplied by the annual water use factor, and the water reduction associated with new buildings for both single family and multifamily dwelling units.
    c. For no change dwelling units, the population is multiplied by the annual water use factor, for both single family and multifamily dwelling units.
3. The indoor water use for replaced buildings, retrofit buildings and no-change buildings is added together at the grid cell or parcel scale to produce total indoor water use for persisting buildings and then summed at the regional scale to produce total persisting base indoor water use for that region.

Step 2a Equation: Residential indoor water use in replaced/remodeled base units of dwelling unit type T by parcel/grid

$$Wi_{rpT} = DU_{rT} * O_R * H_s * C_{rp} * W_T * (1 - R_n)$$

Step 2b Equation: Residential indoor water use in retrofit base units of dwelling unit type T by parcel/grid

$$Wi_{rfT} = DU_{rT} * O_R * H_s * C_{rf} * W_T * (1 - R_{rf})$$

Step 2c Equation: Residential indoor water use in no-change base units of dwelling unit type T by parcel/grid

$$Wi_{ncT} = DU_{rT} * O_R * H_s * \left(1 - (C_{rp} + C_{rf})\right) * W_T$$

Where:

$Wi_{rpT} = Indoor\ water\ use\ by\ replaced\ dwelling\ units\ by\ parcel\ or\ grid$

$Wi_{rfT} = Indoor\ water\ use\ by\ retrofit\ dwelling\ units\ by\ parcel\ or\ grid$

$Wi_{ncT} = Indoor\ water\ use\ by\ no\ change\ dwelling\ units\ by\ parcel\ or\ grid$

$DU_{rT} = Remaining\ number\ of\ base\ year\ dwelling\ units\ of\ type\ T$ *by parcel*

$O_R = Percent\ of\ dwelling\ units\ that\ are\ occupied$

$H_s = Number\ of\ people\ per\ household$

$C_{rp} = Percentage\ of\ persisting\ base\ year\ units\ that\ are\ replaced\ in\ the\ time\ interval$

$C_{rf} = Percentage\ of\ persisting\ base\ year\ units\ that\ are\ retrofit\ in\ the\ time\ interval$

$R_n =$ *Percent reduction in baseline water use in new buildings*

$R_{nr} =$ *Percent reduction in baseline water use in new buildings that are retrofit in the time interval*

$R_{rf} =$ *Percent reduction in baseline water use in retrofit buildings*

$W_T =$ *Gallons of water use per person per day in dwelling unit type T*

$T =$ *Single Family or Multifamily*

Equation 10-3: Total regional future residential indoor water use for dwelling units of type T

$$Wi_{rT} = Wi_{rpT} + Wi_{rfT} + Wi_{ncT}$$

Where:

$Wi_r =$ *Residential indoor water use in persisting dwelling units of type T by parcel or grid*

$Wi_{rpT} =$ *Residential indoor water use in replaced base persisting units of dwelling unit type T by parcel or grid*

$Wi_{rpT} =$ *Residential indoor water use in retrofit base persisting units of dwelling unit type T by parcel or grid*

$Wi_{rpT} =$ *Residential indoor water use in no change base persisting units of dwelling unit type T by parcel or grid*

Equation 10-4: Total residential indoor water use persisting base units of dwelling unit type T for all parcels or grids

$$Wi_p = \sum (Wi_{rSF} + Wi_{rMF})$$

Where:

$Wi_p =$ *Total residential indoor water use by persisting dwelling units for all parcels or grids*

$Wi_{rSF} =$ *Indoor water use by persisting Single Family Units at the parcel or grid scale*

$Wi_{rMF} =$ *Indoor water use by persisting Multifamily Units at the parcel or grid scale*

Future Year Total Residential Indoor Water Use

The total indoor water use for a future scenario is the sum of the new building type indoor water consumption and the persisting building type indoor water consumption. The equation is this:

$$Wi_r = Wi_n + Wi_p$$

Where:

$Wi_r = Total\ residential\ indoor\ water\ use\ for\ all\ parcels\ or\ grids$

$Wi_n = Total\ regional\ indoor\ water\ use\ by\ new\ dwelling\ units$

$Wi_p = Total\ regional\ indoor\ water\ use\ by\ persisting\ dwelling\ units$

Residential Outdoor Water Use: Future Year

Residential outdoor water use in future scenarios is modeled in two parts. First, new residential outdoor water use is modeled and secondly, persisting base year outdoor water use is modeled. This allows for policy assumptions to interact with these populations separately.

Future Year New Residential Outdoor Water Use

The annual outdoor water use of new residential units is calculated via the following steps:

1. The residential irrigated area for each parcel is multiplied by factors reflecting evapotranspiration and irrigation efficiency assumptions, yielding total new residential outdoor water use per year for the grid cell or parcel (expressed in acre-feet).
    a. New irrigated area is divided into two groups, those that are retrofit after new construction and those that maintain their reductions from the time of construction (non-retrofit).
    b. For non-retrofit new irrigated area, the area is multiplied by the annual reference evapotranspiration value corresponding to the location of the grid cell or parcel, the water reduction associated with new construction area and the irrigation efficiency factor (for landscape in California, an adjustment factor of 0.8 is assumed[42]).
    c. For retrofit new irrigated area, the area is multiplied by the annual reference evapotranspiration value corresponding to the location of the grid cell or parcel, the water reduction associated with retrofit new construction area and the irrigation efficiency factor.
2. The water use in non-retrofit new irrigated area and retrofit new irrigated area is added together at the grid cell or parcel scale to produce total new acre feet of outdoor water consumption for new irrigated area.
3. The outdoor water use for new irrigated area is then summed at the regional scale to produce total new outdoor water use for that region.

Step 1b Equation: Residential outdoor water use in new non-retrofit irrigated acres by parcel/grid

$$Wo_{nrT} = I_{nR} * E_r * (1 - C_{nr}) * (1 - R_n) * Ef_r$$

[42] Consol, 2010. *Water Use in the California Residential Home*.

Step 1c Equation: Residential outdoor water use in new irrigated acres by parcel/grid

$$W_{rT} = I_{nR} * E_r * C_{nr} * (1 - R_{nr}) * Ef_r$$

Where:

$Wo_{nrT} = Residential\ outdoor\ water\ use\ by\ non\ retrofit\ new\ irrigated\ acres\ by\ parcel\ or\ grid$

$Wo_{rT} = Residential\ outdoor\ water\ use\ by\ retrofit\ new\ irrigated\ acres\ by\ parcel\ or\ grid$

$I_{nR} = Number\ of\ gross\ new\ residential\ irrigated\ acres\ by\ parcel/grid$

$C_{nr} = Percentage\ of\ new\ irrigated\ acres\ that\ are\ retrofit\ in\ the\ time\ interval$

$R_n = Percent\ reduction\ in\ baseline\ outdoor\ water\ use\ in\ new\ buildings$

$R_{nr} = Percent\ reduction\ in\ baseline\ outdoor\ water\ use\ in\ new\ buildings\ that\ are\ retrofit\ in\ the\ time\ interval$

$E_R = Evapotranspiration\ rate\ per\ year\ (Acre\ feet)\ by\ climate\ zone$

$Ef_R = Regional\ efficiency\ factor$

Step 2 and 3 Equation: Total new residential outdoor water use for all parcels/grids

$$Wo_n = \sum (Wo_{nT} + Wo_{nrT})$$

Where:

$Wo_n = Total\ residential\ outdoor\ water\ use\ by\ new\ irrigated\ acres\ for\ all\ parcels\ or\ grids$

$Wo_{nT} = Residential\ outdoor\ water\ use\ in\ new\ non - retrofit\ irrigated\ acres\ by\ parcel/grid$

$Wo_{nrT} = Residential\ outdoor\ water\ use\ in\ new\ retrofit\ irrigated\ acres\ by\ parcel/grid$

Future Year Persisting Residential Outdoor Water Use

Persisting residential units include those existing in the base year that are subsequently replaced by units of the same time, retrofitted to better standards or do not change. Buildings built to replace existing units lost through redevelopment count as new buildings. The annual outdoor water use of future persisting base residential units is calculated via the following steps and equations which follow:

9. The residential irrigated area for each parcel is multiplied by factors reflecting evapotranspiration and irrigation efficiency assumptions, yielding total residential outdoor water use per year for the grid cell or parcel (expressed in acre-feet).

a. Persisting irrigated area are divided into those that are replaced in the time interval with new standards, those that are retrofit with upgraded standards and those that do not change.

b. For replaced irrigated acres, the area is multiplied by the annual reference evapotranspiration value corresponding to the location of the grid cell or parcel, the water reduction associated with new construction acres and the irrigation efficiency factor.

c. For retrofit irrigated acres, the area is multiplied by the annual reference evapotranspiration value corresponding to the location of the grid cell or parcel, the water reduction associated with retrofit acres and the irrigation efficiency factor.

d. For irrigated acres that do not change, the area is multiplied by the annual reference evapotranspiration value corresponding to the location of the grid cell or parcel and the irrigation efficiency factor.

10. The water outdoor water use for replaced irrigated acres, retrofit irrigated acres and no-change irrigated acres is added together at the grid cell or parcel scale to produce total acre feet of water consumption for persisting irrigated area.

11. The outdoor water use for persisting irrigated area is then summed at the regional scale to produce total persisting base outdoor water use for that region.

Step 1b Equation: Residential outdoor water use in replaced/remodeled irrigated acres by parcel/grid

$$Wo_{rpT} = I_{rR} * C_{rp} * (1 - R_n) * Ef_r * E_r$$

Step 1c Equation: Residential water use in retrofit base units of dwelling unit type t by parcel/grid

$$Wo_{rfT} = I_{rR} * C_{rf} * \left(1 - R_{rf}\right) * Ef_r * E_r$$

Step 1d Equation: Residential water use in no-change base units of dwelling unit type t by parcel/grid

$$Wo_{ncT} = I_{rR} * \left(1 - (C_{rp} + C_{rf})\right) * Ef_r * E_r$$

Where:

$Wo_{rpT} = Residential\ outdoor\ water\ use\ in\ replaced\ irrigated\ acres\ by\ parcel\ or\ grid$

$Wo_{rfT} = Residential\ outdoor\ water\ use\ in\ retrofit\ irrigated\ acres\ by\ parcel\ or\ grid$

$Wo_{ncT} = Residential\ outdoor\ water\ use\ in\ no\ change\ irrigated\ acres\ by\ parcel\ or\ grid$

$I_{rR} = Remaining\ number\ of\ base\ year\ residential\ irrigated\ acres\ by\ parcel/grid$

$C_{rp} = Percent\ of\ persisting\ base\ year\ irrigated\ acres\ that\ are\ replaced\ with\ new\ standards\ in\ the\ time\ interval$

$C_{rf} = Percent\ of\ persisting\ base\ year\ irrigated\ acres\ that\ are\ retrofit\ in\ the\ time\ interval$

$R_n = \ Percent\ reduction\ in\ baseline\ outdoor\ water\ use\ in\ new\ buildings$

$R_{rf} = \ Percent\ reduction\ in\ baseline\ outdoor\ water\ use\ in\ \ retrofit\ buildings$

$Ef_R = Regional\ efficiency\ factor$

$E_R = \ Evapotranspiration\ rate\ per\ year\ (Acre\ feet)\ by\ climate\ zone$

Step 2 and 3 Equation: Total future year persisting residential outdoor water use for all parcels/grids

$$Wo_p = \sum(Wo_{rpT} + \ Wo_{rfT} + \ Wo_{ncT})$$

Where:

$Wo_p = Total\ residential\ outdoor\ water\ use\ by\ persisting\ dwelling\ units\ for\ all\ parcels\ or\ grids$

$Wo_{rpT} = Residential\ outdoor\ water\ use\ in\ replaced\ irrigated\ area\ by\ parcel\ or\ grid$

$Wo_{rfT} = Residential\ outdoor\ water\ use\ in\ retrofit\ irrigated\ area\ by\ parcel\ or\ grid$

$Wo_{rpT} = Residential\ outdoor\ water\ use\ in\ no\ change\ irrigated\ area\ by\ parcel\ or\ grid$

Future Year Total Residential Outdoor Water Use

The total outdoor water use for a future scenario is the sum of the new building type outdoor water consumption and the persisting building type outdoor water consumption. The equation is this:

$$Wo_r = Wo_n \ + \ Wo_p$$

Where:

$Wo_r = Total\ residential\ outdoor\ water\ use\ for\ all\ parcels/grids$

$Wo_n = Total\ regional\ outdoor\ water\ use\ by\ new\ dwelling\ units$

$Wo_p = Total\ regional\ outdoor\ water\ use\ by\ persisting\ dwelling\ units$

Future Year Total Residential Water Use

Total residential water use in a future scenario is the sum of annual residential indoor water use and the sum of annual residential outdoor water use derived from the previously noted equations. The equation for total water use is as follows:

Equation 10-5: Total annual residential water use

$$W_r = Wi_r + Wo_r$$

Where:

$W_r = Total\ annual\ residential\ water\ use$

$Wi_r = Total\ annual\ residential\ indoor\ water\ use$

$Wo_r = Total\ annual\ residential\ outdoor\ water\ use$

Base Year Commercial Indoor Water Use

The annual commercial base year indoor water use is calculated using the per capita water use associated with employment types. In UrbanFootprint, these types are retail, office, education and industrial and each have associated water use factors. Base year commercial water use is modeled in these steps:

1. For each employment type, the associated gallons per capita per day factor is applied to the number of employees at the parcel scale and multiplied by the annualization factor to derive annual indoor water use in gallons.
2. The water use from all employment types are added together at the parcel scale and then summed to the region.

Step 1 Equation: Commercial indoor water use in the base year of employment type T by parcel/grid

$$\boldsymbol{Wi_T = E_T * W_T * A_r}$$

Where:

$\mathrm{Wi_T} = Commercial\ indoor\ water\ use\ of\ employment\ type\ T\ by\ parcel\ or\ grid$

$E_T =\ Base\ Year\ number\ of\ employees\ of\ employment\ type\ T\ by\ parcel\ or\ grid\ cell$

$W_T =\ Gallons\ of\ water\ use\ per\ employee\ per\ day\ in\ commercial\ unit\ type\ T$

$A_r = Annualization\ Factor$

Step 2 Equation: Total regional base commercial indoor water use for all parcels or grids

$$Wi_c = \sum(Wi_{Ret} + Wi_{Off} + Wi_{Ed} + Wi_{Ind})$$

Where

$Wi_c = Total\ commercial\ indoor\ water\ use\ for\ all\ parcels\ or\ grids$

$Wi_{Ret} = Total\ indoor\ water\ use\ by\ Retail\ Employees$

$Wi_{Off} = Total\ indoor\ water\ use\ by\ Office\ Employees$

$Wi_{Ed} = Total\ indoor\ water\ use\ by\ Education\ Employees$

$Wi_{Ind} = Total\ indoor\ water\ use\ by\ Industrial\ Employees$

Base Year Commercial Outdoor Water Use

The annual commercial base year outdoor water use is calculated using the irrigated area associated with each parcel in a region. Outdoor water use is dependent on this parcel level attribute, the climate zone specific evapotranspiration rate and the irrigation efficiency rate. It is modeled in these steps:

3. Commercial irrigated area is multiplied by the climate zone evapotranspiration rate and the commercial irrigation efficiency rate.
4. Outdoor water use is then summed to the region to produce total base year outdoor water use in acre-feet.

Steps 1 and 2 Equation: Total base year commercial outdoor water use for all parcels/grids

$$Wo_c = \sum(I_c * E_R * Ef_c)$$

Where:

$Wo_c = Total\ commercial\ outdoor\ water\ use\ for\ all\ parcels\ or\ grids$

$I_c =\ Base\ year\ commercial\ irrigated\ acres\ by\ parcel$

$E_R = Evapotranspiration\ rate\ per\ year\ (Acre\ feet)\ by\ climate\ zone$

$Ef_c = Regional\ commercial\ irrigation\ efficiency\ factor$

Base Year Total Annual Commercial Water Use

Total commercial water use is the sum of annual commercial indoor water use and the sum of annual commercial outdoor water use. The equation is as follows:

Equation 10-6: Total annual commercial water use for all parcels/grids

$$W_c = Wi_c + Wo_c$$

Where:

$W_c = Total\ annual\ commercial\ water\ use\ for\ all\ parcels\ or\ grids$

$Wi_c = Total\ annual\ commercial\ indoor\ water\ use$

$Wo_c = Total\ annual\ commercial\ outdoor\ water\ use$

Commercial Indoor Water Use: Future Year

Commercial indoor water use in future scenarios is modeled in two parts. First, new commercial indoor water use is modeled and secondly, persisting base year indoor water use is modeled. This allows for policy assumptions to interact with these populations separately.

Future Year New Commercial Indoor Water Use

The annual commercial indoor water by new employees is calculated via the following steps:

5. Employees are grouped into whether the buildings they were associated with were retrofit in the interval or if the buildings maintained the water consumption reductions associated with the time they were built (non-retrofit)
7. For each retrofit and non-retrofit employee totals by employment type, these are multiplied by the per capita water use factors corresponding to each employment type.
8. The non-retrofit reduction factor base on construction efficiency assumptions is applied to the non-retrofit employee water use for each employment type.
9. The retrofit reduction factor base on construction efficiency assumptions and further retrofits is applied to the retrofit employee water use for each employment type.
10. The retrofit and non-retrofit employee water uses are summed together for each employment type at the parcel or grid cell scale.
11. Parcel or grid cell scale indoor water use by employment type are added together and summed to the scale of the scenario or other user-defined geography, yielding total indoor water use by new employees.

Equations Steps 1 – 4:

Commercial indoor water use in non-retrofit new employee water use in employment type T by parcel/grid

$$Wi_{nrT} = E_T * (1 - C_{nr}) * \ W_T * (1 - R_n)$$

Commercial indoor water use in retrofit new employee water use in employment type T by parcel/grid

$$Wi_{rT} = E_T * C_{nr} * W_T * (1 - R_{nr})$$

Where:

$Wi_{nrT} = Commercial\ indoor\ water\ use\ by\ non\ retrofit\ buildins\ in\ employment\ type\ T\ by\ parcel\ or\ grid$

$Wi_{rT} = Commercial\ indoor\ water\ use\ by\ non\ retrofit\ buildins\ in\ employment\ type\ T\ by\ parcel\ or\ grid$

$E_T = Number\ of\ \ employees\ in\ employment\ type\ T$ *by parcel*

$C_{nr} = Percentage\ of\ new\ employee\ water\ uses\ that\ are\ retrofit\ in\ the\ time\ interval$

$R_n = Percent\ reduction\ in\ baseline\ water\ use\ in\ \ new\ buildings$

$R_{nr} = Percent\ reduction\ in\ baseline\ water\ use\ in\ \ new\ buildings\ that\ are\ retrofit\ in\ the\ time\ interval$

$W_T = Gallons\ of\ water\ use\ per\ employee\ per\ day\ in\ dwelling\ unit\ type\ T$

Step 5 Equation: Commercial indoor water use by new commercial units of type T bay parcel/grid

$$Wi_{nT} = Wi_{rT} + Wi_{nrT}$$

Where:

$Wi_{nT} = Commercial\ indoor\ water\ use\ by\ new\ buildigns\ of\ employment\ type\ T\ by\ parcel\ or\ grid$

$Wi_{rT} = Indoor\ water\ use\ in\ non\ retrofit\ commercial\ buildings\ of\ employment\ type\ T$

$Wi_{nrT} = \ Indoor\ water\ use\ in\ retrofit\ new\ commercial\ buildings\ ofemployment\ type\ T$

Step 6 Equation: Total future commercial indoor water use by new employees for all parcels/grids

$$Wi_n = \sum (Wi_{nRet} + Wi_{nOff} + Wi_{nEd} + Wi_{nInd})$$

Where:

$Wi_n = Total\ commercial\ indoor\ water\ use\ by\ new\ employees\ for\ all\ parcels\ or\ grids$

$Wi_{nRet} = Total\ indoor\ water\ use\ by\ new\ Retail\ Employees$

$Wi_{nOff} = Total\ indoor\ water\ use\ by\ new\ Office\ Employees$

$Wi_{nEd} = Total\ indoor\ water\ use\ by\ new\ Education\ Employees$

$Wi_{Innd} = Total\ \ indoor\ water\ use\ by\ new\ Industrial\ Employees$

Future Year Persisting Commercial Indoor Water Use

The annual indoor water use by persisting employees in a future scenario is modeled in three parts, those employees water use that are replaced with new efficiencies, those that are retrofit with improved water efficiencies and those that do not change in the interval. The annual indoor water use of future persisting base employees is calculated via the following steps and equations which follow:

1. The buildings associated with each parcel population are divided into those that are replaced in the time interval with new standards, those that are retrofit with upgraded standards, and those that do not change (as described on page 7).
    a. For replaced employee water use, the number of employees is multiplied by the annual water use factor, the water reduction associated with new employee water use for each employment type.
    b. For retrofit employee water use, the number of employees is multiplied by the annual water use factor, the water reduction associated with retrofit employee water use by employment type.
    c. For no-change employee water use, the number of employees is multiplied by the annual water use factor by employment type.
2. The indoor water use for replaced employee water use, retrofit employee water use, and no-change employee water use is added together at the grid cell or parcel scale employment type.
3. To produce total indoor water use for persisting employees, the total indoor water use by employment type is summed to the region.

Step 1a Equation: Commercial indoor water use by replaced employee water use of employment type T by parcel/grid

$$Wi_{rpT} = E_{rT} * C_{rp} * W_T * (1 - R_n)$$

Step 1b Equation: Commercial indoor water use by retrofit employee water use of employment type T by parcel/grid

$$Wi_{rfT} = E_{rT} * C_{rf} * W_T * (1 - R_{rf})$$

Step 1c Equation: Commercial indoor water use by no-change employee water use of employment type T by parcel/grid

$$Wi_{ncT} = E_{rT} * \left(1 - (C_{rp} + C_{rf})\right) * W_T$$

Where:

$Wi_{rpT} = Commercial\ indoor\ water\ use\ in\ replaced\ buildings\ of\ type\ T\ by\ parcel\ or\ grid$

$Wi_{rfT} = Commercial\ indoor\ water\ use\ in\ retrofit\ buildings\ of\ type\ T\ by\ parcel\ or\ grid$

$Wi_{ncT} = Commercial\ indoor\ water\ use\ in\ no\ change\ buildings\ of\ type\ T\ by\ parcel\ or\ grid$

$E_{rT} = Remaining\ number\ of\ base\ year\ employees\ of\ type\ T$ *by parcel*

$C_{rp} =$ $Percentage\ of\ persisting\ base\ year\ employees\ (proxy\ for\ built\ form)\ that\ are\ replaced\ in\ the\ time\ interval$

$C_{rf} = Percentage\ of\ persisting\ base\ year\ employees\ \ (proxy\ for\ built\ form)\ that\ are\ retrofit\ in\ the\ time\ interval$

$R_n =$ $Percent\ reduction\ in\ baseline\ water\ use\ in\ \ new\ buildings$

$R_{nr} =$ $Percent\ reduction\ in\ baseline\ water\ use\ in\ \ new\ buildings$ *that are retrofit in the time interval*

$R_{rf} =$ $Percent\ reduction\ in\ baseline\ water\ use\ in\ \ retrofit\ buildings$

$W_T =$ $Gallons\ of\ water\ use\ per\ person\ per\ day\ in\ employment\ type\ T$

Step 2 Equation: Future commercial indoor water use by persisting employees in employment type T by parcel/grid

$$Wi_{pT} = Wi_{rpT}\ +\ Wi_{rfT}\ +\ Wi_{ncT}$$

Where:

$Wi_{pT} = Commercial\ indoor\ water\ by\ persisting\ employees\ of\ employment\ type\ T\ by\ parcel\ or\ grid$

$Wi_{rpT} = Commerical\ indoor\ water\ use\ in\ replaced\ employee\ water\ use\ of\ employment\ type\ T\ by\ parcel\ or\ grid$

$Wi_{rfT} = Commerical\ indoor\ water\ use\ in\ retrofit\ employee\ water\ use\ of\ employment\ type\ T\ by\ parcel\ or\ grid$

$Wi_{ncT} = Commercial\ indoor\ water\ use\ in\ no\ change\ employee\ water\ use\ of\ employment\ type\ T\ by\ parcel\ or\ grid$

Step 3 Equation: Total future commercial indoor water use by persisting employees for all parcels/grids

$$Wi_p = \sum(Wi_{pRet} + Wi_{pOff}\ + Wi_{pEd}\ + Wi_{pInd})$$

Where:

$Wi_p = Total\ commercial\ indoor\ water\ use\ by\ persisting\ employees\ for\ all\ parcels\ or\ grids$

$Wi_{pRet} = Indoor\ water\ use\ by\ persisting\ Retail\ Employees\ by\ parcel\ or\ grid$

$Wi_{pOff} = Indoor\ water\ use\ by\ persisting\ Office\ Employees\ by\ parcel\ or\ grid$

$Wi_{pEd} = Indoor\ water\ use\ by\ persisting\ Education\ Employees\ by\ parcel\ or\ grid$

$Wi_{pInd} = Indoor\ water\ use\ by\ persisting\ Industrial\ Employees\ by\ parcel\ or\ grid$

Future Year Total Indoor Water Use

The total indoor water use for a future scenario is the sum of new employee indoor water consumption and the persisting employee indoor water consumption. The equation is this:

$$Wi_c = Wi_n\ +\ Wi_p$$

Where:

$Wi_c = Total\ commercial\ water\ use\ for\ all\ parcels\ or\ grids$

$Wi_n = Total\ regional\ indoor\ water\ use\ by\ new\ employees$

$Wi_p = Total\ regional\ indoor\ water\ use\ by\ persisting\ employees$

Commercial Outdoor Water Use: Future Year

Commercial outdoor water use in future scenarios is modeled in a similar fashion to residential outdoor water use. First, new commercial outdoor water use is modeled and secondly, persisting base year outdoor water use is modeled. This allows for policy assumptions to interact with these populations separately.

Future Year New Commercial Outdoor Water Use

The annual outdoor water use of new commercial buildings is calculated via the following steps:

12. The commercial irrigated area for each parcel is multiplied by factors reflecting evapotranspiration and irrigation efficiency assumptions, yielding total new commercial outdoor water use per year for the grid cell or parcel (expressed in acre-feet).
    a. New irrigated area is divided into two groups, those that are retrofit after new construction and those that maintain their reductions from the time of construction (non-retrofit).
    b. For non-retrofit new irrigated area, the area is multiplied by the annual reference evapotranspiration value corresponding to the location of the grid cell or parcel, the water reduction associated with new construction area and the irrigation efficiency factor.
    c. For retrofit new irrigated area, the area is multiplied by the annual reference evapotranspiration value corresponding to the location of the grid cell or parcel, the water reduction associated with retrofit new construction area and the irrigation efficiency factor.
13. The water use in non-retrofit new irrigated area and retrofit new irrigated area is added together at the grid cell or parcel scale to produce total new acre feet of outdoor water consumption for new irrigated area.
14. The outdoor water use for new irrigated area is then summed at the regional scale to produce total new outdoor water use for that region.

Step 1b Equation: Commercial outdoor water use in new non-retrofit irrigated acres by parcel/grid

$$Wo_{nrT} = I_{nR} * E_r * (1 - C_{nr}) * (1 - R_n) * Ef_r$$

Step 1c Equation: Commercial outdoor water use in new irrigated acres by parcel/grid

$$Wo_{rT} = I_{nR} * E_r * C_{nr} * (1 - R_{nr}) * Ef_r$$

Where:

$Wo_{nrT} = Commercial\ outdoor\ water\ use\ in\ new\ non\ retrofit\ irrigated\ acres\ by\ parcel\ or\ grid$

$Wo_{rT} = Commercial\ outdoor\ water\ use\ in\ new\ retrofit\ irrigated\ acres\ by\ parcel\ or\ grid$

$I_{nR} = \ Number\ of\ gross\ new\ commercial\ irrigated\ acres\ by\ parcel/grid$

$C_{nr} = \ Percentage\ of\ new\ irrigated\ acres\ that\ are\ retrofit\ in\ the\ time\ interval$

$R_n = \ Percent\ reduction\ in\ baseline\ outdoor\ water\ use\ in\ new\ buildings$

$R_{nr} = \ Percent\ reduction\ in\ baseline\ outdoor\ water\ use\ in\ new\ buildings\ that\ are\ retrofit\ in\ the\ time\ interval$

$E_R = \ Evapotranspiration\ rate\ per\ year\ (Acre\ feet)\ by\ climate\ zone$

$Ef_R = Regional\ efficiency\ factor$

Step 2 and 3 Equation: Total new commercial outdoor water use for all parcels/grids

$$Wo_n = \sum(Wo_{rT} + Wo_{nrT})$$

Where:

$Wo_n = Total\ new\ commercial\ outdoor\ water\ use\ for\ all\ parcels\ or\ grids$

$WO_{rT} = Commercial\ outdoor\ water\ use\ in\ new\ non-retrofit\ irrigated\ acres\ by\ parcel/grid$

$WO_{nrT} = Commercial\ outdoor\ water\ use\ in\ new\ retrofit\ irrigated\ acres\ by\ parcel/grid$

Future Year Persisting Commercial Outdoor Water Use

Persisting commercial buildings include those existing in the base year that are subsequently replaced by units of the same time, retrofitted to better standards or do not change. Buildings built to replace existing units lost through redevelopment count as new buildings. The annual outdoor water use of future persisting base commercial units is calculated via the following steps and equations which follow:

1. The commercial irrigated area for each parcel is multiplied by factors reflecting evapotranspiration and irrigation efficiency assumptions, yielding total commercial outdoor water use per year for the grid cell or parcel (expressed in acre-feet).
    a. Persisting irrigated area are divided into those that are replaced in the time interval with new standards, those that are retrofit with upgraded standards and those that do not change.
    b. For replaced irrigated acres, the area is multiplied by the annual reference evapotranspiration value corresponding to the location of the grid cell or parcel, the water reduction associated with new construction acres and the irrigation efficiency factor.

c. For retrofit irrigated acres, the area is multiplied by the annual reference evapotranspiration value corresponding to the location of the grid cell or parcel, the water reduction associated with retrofit acres and the irrigation efficiency factor.

d. For irrigated acres that do not change, the area is multiplied by the annual reference evapotranspiration value corresponding to the location of the grid cell or parcel and the irrigation efficiency factor.

2. The water outdoor water use for replaced irrigated acres, retrofit irrigated acres and no-change irrigated acres is added together at the grid cell or parcel scale to produce total acre feet of water consumption for persisting irrigated area.
3. The outdoor water use for persisting irrigated area is then summed at the regional scale to produce total persisting base outdoor water use for that region.

Step 1b Equation: Commercial outdoor water use in replaced irrigated acres by parcel/grid

$$Wo_{rpT} = I_{cR} * C_{rp} * (1 - R_n) * Ef_c * E_r$$

Step 1c Equation: Commercial outdoor water use in retrofit irrigated acres by parcel/grid

$$Wo_{rfT} = I_{cR} * C_{rf} * \left(1 - R_{rf}\right) * Ef_c * E_r$$

Step 1d Equation: Commercial outdoor water use in no-change irrigated acres by parcel/grid

$$Wo_{ncT} = I_{cR} * \left(1 - (C_{rp} + C_{rf})\right) * Ef_c * E_r$$

Where:

$Wo_{rpT} = Commercial\ outdoor\ water\ use\ by\ replaced\ irrigated\ acres\ by\ parcel\ or\ grid$

$Wo_{rfT} = Commercial\ outdoor\ water\ use\ by\ retrofit\ irrigated\ acres\ by\ parcel\ or\ grid$

$Wo_{ncT} = Commercial\ outdoor\ water\ use\ by\ no\ change\ irrigated\ acres\ by\ parcel\ or\ grid$

$I_{cR} = Remaining\ number\ of\ base\ year\ commercial\ irrigated\ acres\ by\ parcel/grid$

$C_{rp} = Percent\ of\ persisting\ base\ year\ irrigated\ acres\ that\ are\ replaced\ with\ new\ standards\ in\ the\ time\ interval$

$C_{rf} = Percent\ of\ persisting\ base\ year\ irrigated\ acres\ that\ are\ retrofit\ in\ the\ time\ interval$

$R_n = Percent\ reduction\ in\ baseline\ outdoor\ water\ use\ in\ new\ buildings$

$R_{rf} = Percent\ reduction\ in\ baseline\ outdoor\ water\ use\ in\ retrofit\ buildings$

$Ef_c = Regional\ efficiency\ factor$

$E_R = Evapotranspiration\ rate\ per\ year\ (Acre\ feet)\ by\ climate\ zone$

Step 2 and 3 Equation: Total future year persisting commercial outdoor water use for all parcels/grids

$$Wo_p = \sum(Wo_{rpT} + Wo_{rfT} + Wo_{ncT})$$

Where:

$Wo_p = Total\ commercial\ outdoor\ water\ use\ for\ all\ parcels\ or\ grids$

$Wo_{rpT} = Commercial\ outdoor\ water\ use\ in\ replaced\ irrigated\ area\ by\ parcel\ or\ grid$

$Wo_{rfT} = Commercial\ outdoor\ water\ use\ in\ retrofit\ irrigated\ area\ by\ parcel\ or\ grid$

$Wo_{rpT} = Commercial\ outdoor\ water\ use\ in\ no\ change\ irrigated\ area\ by\ parcel\ or\ grid$

Future Year Total Outdoor Water Use

The total outdoor water use for a future scenario is the sum of new irrigated area water consumption and the persisting irrigated area water consumption. The equation is this:

$$Wo_c = Wo_n + Wo_p$$

Where:

$Wo_c = Total\ commercial\ outdoor\ water\ use\ for\ all\ parcels\ or\ grids$

$Wo_n = Total\ regional\ outdoor\ water\ use\ on\ persisting\ \ irrigated\ area$

$Wo_p = Total\ regional\ outdoor\ water\ use\ on\ persisting\ \ irrigated\ area$

Future Year Total Annual Commercial Water Use

Total commercial water use is the sum of annual commercial indoor water use and the sum of annual commercial outdoor water use. The equation is as follows:

Equation 10-7: Total annual commercial water use

$$W_c = Wi_c + Wo_c$$

Where:

$W_c = Total\ commercial\ water\ use\ for\ all\ parcels\ or\ grids$

$Wi_c = Total\ annual\ commercial\ indoor\ water\ use$

$Wo_c = Total\ annual\ commercial\ outdoor\ water\ use$

Water Cost

UrbanFootprint calculates water costs on the basis of water use metrics and projected retail prices for residential and commercial water supply. The model assumes an increase in the retail price of water over time, which may occur as a function of pricing strategies to reduce water use.

Basis for Assumptions

The default California per-acre foot price assumption ($888 per acre-foot in 2005 dollars) is derived from values for average annual household water use and water bills in California[43]. By default, the model assumes that prices for all years increase at a rate of 1.1% annually (in constant dollars), a value based on historic water-price surveys in California between 1991 and 2001[44].

This price increase, which is equivalent to a 41% increase over 30 years, is relatively high compared to that of the California Water Plan Update “Current Trends” scenario[45], which specifies a “modest” average increase in price of 20% over 30 years[46]. Higher water prices can be projected to reflect a number of variables, from infrastructure costs to strategies that seek to reduce water use through pricing adjustments. The Pacific Institute, a research and policy analysis organization, relates the 1.1% annual price increase assumption to a “High Efficiency” scenario[47]. As with all UrbanFootprint assumptions, the default inputs can be easily changed to test the effects of different factors or policy options.

Water Cost Calculations

Water cost estimates are calculated by applying water prices to the calculated water use figures to arrive at costs. Annual costs are calculated as shown in Equation 10-8.

Equation 10-8: Annual water cost

$$D_{\mathrm{w}} = W_x * P_x$$

where:

D_w = Total annual cost (dollars) for water used by all units built up to year x

W_x = Water used for all units built up to year x (acre-feet)

P_x = Price per acre-foot in year x

x = Any year

[43] (Public Policy Institute of California, 2008)

[44] (Gleick, Cooley, & Groves, 2005)

[45] (California Department of Water Resources, 2005)

[46] (Gleick, Cooley, & Groves, 2005)

[47] (Gleick, Cooley, & Groves, 2005)

Water-Related Energy Use and Greenhouse Gas Emissions

Water-related energy use and greenhouse gas (GHG) emissions refer to those resulting from two main water-related energy use categories: a) *system uses*, including the transport and treatment of residential water consumed; and b) *end uses*, including all uses of water that occur within homes (e.g., water heating). UrbanFootprint calculates energy use and emissions for water system uses only, since these can be considered as a discrete component of a GHG emissions inventory (along with transportation-related and building energy emissions). Water end-use emissions are counted as part of building energy emissions.

Water-Related Energy Use and GHG Emissions Factors

The system uses related to water include the energy used for water supply, conveyance, treatment, distribution, and wastewater treatment. The per-gallon energy use factors associated with these stages of the water cycle were estimated by the CEC in a 2005 report, *California's Water-Energy Relationship*[48], and a 2006 refinement of the report's original factors[49]. The CEC study represents the best-available data on statewide water-related energy use. These energy intensity factors (also called "water-energy proxies") were determined for indoor and outdoor water uses in Northern and Southern California, as shown in Table 10-6: CEC Water-Energy Intensity Factors.

Table 10-6: CEC Water-Energy Intensity Factors

	Indoor Uses		Outdoor Uses	
	Northern California kWh/MG	**Southern California kWh/MG**	**Northern California kWh/MG**	**Southern California kWh/MG**
Water Supply and Conveyance	2,117	9,727	2,117	9,727
Water Treatment	111	111	111	111
Water Distribution	1,272	1,272	1,272	1,272
Wastewater Treatment	1,911	1,911	0	0
Regional Total	**5,411**	**13,022**	**3,500**	**11,111**

Because most of the water used in Southern California is transported from long distances (often across state lines), the energy intensity of water supply and conveyance is much higher than in Northern California. The factors are applied to indoor and outdoor water use totals by location, and are assumed to remain constant over time.

Water system energy includes electricity use only; natural gas is not used directly. The GHG emission rates per kilowatt-hour of water-related electricity use are assumed to be the same as for building energy use. (Refer to the Building Energy Analysis Methodology for a detailed description.)

[48] (California Energy Commission, 2005)

[49] (Navigant Consulting, Inc., 2006)

Water-Related Energy Use and GHG Emissions Calculations

Emissions related to water-system energy use are calculated using the per-gallon water-energy intensity assumptions, and the per-kWh electricity emissions rate. Emissions are calculated after first calculating energy use.

Water System Energy Use

Water system energy use is the product of water use and per-gallon energy intensity factors. It is calculated as shown in Equation 10-9.

Equation 10-9: Annual water-system energy use

$$E_x = W_x * i$$

where:

E_x	=	Annual water-system energy associated with water used by all units built within a single year (kWh)
W_x	=	Annual water used by all units built within a single year (million gallons)
i	=	Water-energy intensity factor (kWh/million gallons)
x	=	Any year in the model

Water-Related GHG Emissions

Annual water-system energy emissions are calculated by multiplying annual water system energy use by an electricity emissions rate, as shown in Equation 10-10.

Equation 10-10: Annual emissions from water-system energy use.

$$G_x = E_x * r_x$$

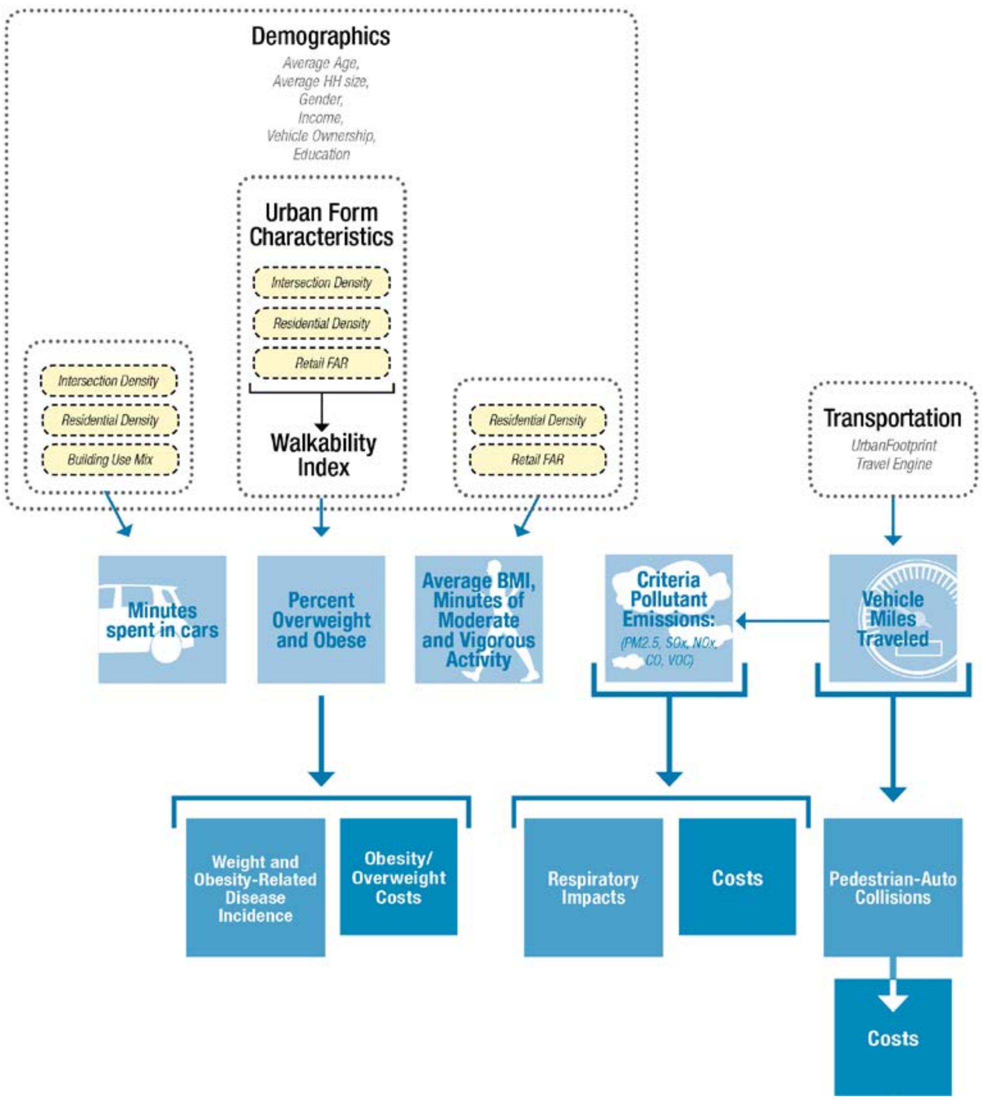
where:

G_x	=	Annual emissions from water-system energy used by all units built within a single year (lbs)
E_x	=	Annual water-system energy associated with water used by all units built within a single year (kWh)
r_x	=	Electricity emission rate (lbs/kWh) for year x
x	=	Any year in the model

CHAPTER 11
Public Health

UrbanFootprint seeks to measure health impacts in order to bring health indicators into the scenario planning and testing process and estimate health related impacts of alternative transportation and land development scenarios. As most planners and policymakers recognize, the combination of transportation systems and land use patterns influences the relative speed, out-of-pocket cost, convenience, and comfort of different travel options. These factors subsequently impact how individuals choose to travel and how they spend their time, which affect activity levels and health. This basic conceptual premise is the focus of UrbanFootprint's health impacts module, and frames the data sources, methods, and approaches discussed in this section.

Figure 11-1: Conceptual Public Health Model Flow



UrbanFootprint measures the impact of land use patterns and urban form on a range of health-related indicators. Public health metrics are measured within two broad categories: those that are derived from factors that are influenced by changes in urban form, including physical activity-related weight and disease incidences; and those that are derived from changes in travel behavior (as expressed by Vehicle Miles Traveled [VMT] and derivative metrics), including pedestrian safety measures and pollution-related respiratory impacts. In all cases, related costs are estimated to highlight the fiscal implications of comparative land use + transportation scenarios (see Figure 11-1).

The public health metrics that UrbanFootprint measures based on changes in urban form rely on regression models built by Urban Design 4 Health (UD4H) based on their own research and data. The obesity-related disease incidence models, fiscal impacts of obesity models, pedestrian safety collision model, and fiscal impacts of collision models were derived by UD4H from published research articles. The respiratory impacts models and fiscal impacts of respiratory conditions models were derived by TIAX, LLC, on behalf of the American Lung Association in California, from published research articles.

Before the public health models can be run within UrbanFootprint to predict health outcomes, a series of pre-process steps are performed to summarize demographic variables into the schema used by the various components of the health module, and to produce intermediate variables such as walkability and building use mix. The models also use, as input, the VMT results produced by UrbanFootprint's travel module.

All public health models produce predictions that enable comparison not only across the range of future scenarios, but between base year and future states.

The Impact of Urban Form: Weight and Activity-Related Metrics

The form of the built environment influences physical activity – for instance, residents of a compact, mixed-use neighborhood are more likely to walk as a part of their regular routine, whereas residents of a low-density residential suburb are likely to spend more time in cars. UrbanFootprint measures the characteristics of urban form that have a demonstrated link to physical activity levels; these are processed into a form useable by the public health module as a set of pre-processes. Those pre-processes used to measure the relevant aspects of urban form include:

1. The walkability index
2. The building use mix measurement
3. The dwelling unit density measurement
4. A network-based walkable street intersection count and density measurement

The public health engine models five primary weight and physical activity metrics for the adult population:

1. Minutes per day of moderate and vigorous physical activity (MVPA)
2. Daily time spent in cars
3. Percent of the adult population that is overweight and obese

4. Percent of the adult population that is obese
5. Average BMI (body mass index)[50]

The amount of physical activity influences the amount of calories burned, which influences body weight, which in turn influences certain health outcomes such as cardiovascular disease and diabetes. Physical activity is measured using average daily minutes of moderate and vigorous physical activity (MVPA) as well as adult daily time spent in cars; body weight is measured by average body mass index and the percent of the adult population that is overweight and obese; related health outcomes are measured as a separate step (see the "Health Impacts of Obesity/Overweight" section). In this initial version (v1.0) of UrbanFootprint's health module, MVPA and average car time are not directly used as inputs to any models of health outcomes; rather, they are produced as indicators of the effects of urban form on physical activity levels. The health outcomes that depict the effects of the level of physical activity all flow from the models predicting adult overweight and obese percentages.

These health outcome metrics are calculated by UrbanFootprint at the grid-cell geography using a series of regression models grounded in primary research conducted by Urban Design 4 Health (UD4H). The model predicting time spent in cars was built using data from a regional transportation study conducted as part of the Atlanta Regional Commission's Household Travel Survey,[51] and the weight and physical activity models were derived from data from the Neighborhood Quality of Life Study in Seattle and King County, Washington (www.nqls.org).[52] [53] Where possible, data from California Health Interview Survey (CHIS)[54] and the San Diego Council of Governments (SANDAG)[55] was used to validate the use of the public health models in California.

[50] The first three indicators are all correlated with adult Body Mass Index (BMI), though each is estimated independently in UrbanFootprint. The links between behavior (such as MVPA, time spent in cars and adult obesity) and BMI are intended to provide some understanding of how behavior has an impact on health. However, it should be noted that the links between behavioral outcomes and BMI are not used to directly measure BMI itself within UrbanFootprint. Rather, only the BMI model is used to assess BMI; while it would be possible to estimate BMI from MVPA, this method would be less accurate than measuring BMI directly; and estimating BMI both directly and indirectly from MVPA would result in "double-counting."

[51] Frank LD, Andresen M, Schmid TL, 2004. Obesity Relationships With Community Design, Physical Activity, and Time Spent in Cars. American Journal of Preventive Medicine. Vol 27. No 2: pp. 87-96.

[52] Sallis, J, Saelens, B, Frank, L, Conway, T, Kerr, J, Cain, K, Chapman, J. Neighborhood Quality of Life Study (www.nqls.org). National Heart, Lung, and Blood Institute Grant HL67350

[53] Frank, L. D., Sallis, J. F., Conway, T. L., Chapman, J. E., Saelens, B. E., & Bachman, W. Many Pathways From Land Use to Health: Associations Between Neighborhood Walkability and Active Transportation, Body Mass Index, and Air Quality. *Journal of the American Planning Association, 72(1)*, 75–87. 2006.

[54] California Health Interview Survey. CHIS 2009 Adult Public Use File, Los Angeles, CA: UCLA Center for Health Policy Research. Available: www.chis.ucla.edu/ (accessed June 21, 2012).

[55] Urban Design 4 Health, Inc. Unpublished data used for Health Impact and Forecasting Assessment, Project No. 5001527 for The San Diego Association of Governments. June, 2012.

Intermediate Variables: Measuring Urban Form Indicators

The weight and activity-related models use a set of intermediate variables calculated at the grid-cell level, including:

- ***Building Use Mix***. Measures the evenness of the distribution of residential, retail, office, and service sector building square feet within a one-kilometer grid-cell buffer. Higher mix indicates a better ability to walk to multiple different types of destinations within close proximity. A primary input to the time spent in cars indicator.
- ***Dwelling Unit Density***. A measure of housing density within a one-kilometer grid-cell buffer. Locations with higher housing density tend to be more compact and located in close proximity to jobs, shops, transit service, and other destinations. A critical input to the MVPA, BMI, and car time models and to the walkability index used in the overweight/obesity models.
- ***Network-Based Street Intersection Count and Density***. An estimate of network-based walkable street connectivity within a one kilometer grid-cell buffer. Higher street connectivity provides more direct walking opportunities and is indicative of a more compact development pattern. An input to both the walkability index and the time spent in cars indicator.
- ***Retail Floor-to-Area Ratio (FAR)***. A measure of the size and lot coverage of retail development. High FAR indicates multi-story buildings covering a large portion of the lot, which low FAR indicates single story buildings covering a small portion of the lot, with the remainder often dedicated to surface parking. An input to the MVPA and BMI models and to the walkability index used in the overweight/obesity models.
- ***Walkability Index***. Produces a walkability rating by combining the dwelling unit density, retail floor-area ratio, and walkable street intersection density variables described above into a single index variable. Each of the three component variables was converted to a z-score, then summed together into the final index value. Higher values indicate locations more supportive of walking, while lower values indicate locations less supportive of walking. In a sample of 1,228 adults in the Neighborhood Quality of Life Study (NQLS) in King County, Washington, it was found that a 5 percent increase in a walkability index was associated with a 0.23-point reduction in BMI after adjusting for gender, age, education, ethnicity, number of children under age 18, and household income (Frank et al. 2006). This input was used in the overweight/obesity models.
- ***Household Income Categories Ranking Mean***. A weighted average of the count of households in various income groups in each grid cell. An input to the time spent in cars, MVPA, and BMI models.
- ***Educational Attainment Categories Ranking Mean***. A weighted average of the count of population by educational attainment in each grid cell. An input to the time spent in cars, MVPA, and BMI models.

A series of coefficients, unique to each model, was applied to these intermediate variables as a part of a regression analysis to estimate primary metrics; see the “Primary Metrics: Weight- and Activity-Related Regression Models” section for more.

Walkability Index

The walkability index is calculated based on the residential use densities, retail floor-area ratio (FAR), and walkable street intersection density within one kilometer of the analysis geography.

Equation 11-1: Walkability Index

$$W_i = \left(\frac{RDU_{ud1km} - RDU_{mud1km}}{RDU_{stdud1km}}\right) + \left(\left(\frac{FER_{u1km} - FER_{mu1km}}{FER_{stdu1km}}\right) + \left(\frac{ID_{sqkmn} - ID_{msqkmn}}{ID_{stdsqkmn}}\right)\right)$$

where:

W_i = **ph_walkability_idx:** Walkability index for individual grid cell "i" for the public health module

RDU_{ud1km} = **use_du_dens_onekm:** Residential use density of dwelling units within one kilometer of individual grid cell "i"

RDU_{mud1km} = **mean_use_du_dens_onekm:** NQLS sample mean residential use density of dwelling units within one kilometer (equal to: 12.59932)

$RDU_{stdud1km}$ = **stdev_use_du_dens_onekm:** NQLS sample standard deviation for the residential use density of dwelling units within one kilometer (equal to: 14.94911)

FER_{u1km} = **retail_use_far_onekm:** Retail use FAR within one kilometer of individual grid cell "i"

FER_{mu1km} = **mean_retail_use_far_onekm:** NQLS sample mean retail use FAR of retail space within one kilometer (equal to: 0.3979)

$FER_{stdu1km}$ = **stdev_retail_use_far_onekm:** NQLS sample standard deviation for the retail use FAR within one kilometer (equal to: 0.311614)

ID_{sqkmn} = **intersection_density_sqkm_network:** Density of walkable street intersections measured within a one kilometer network buffer of individual grid cell "i"

ID_{msqkmn} = **mean_intersection_density_sqkm_network:** NQLS sample mean density of walkable street intersections measured within a one kilometer network buffer (equal to: 63.69303)

$ID_{stdsqkmn}$ = **stdev_intersection_density_sqkm_network:** NQLS sample standard deviation for the density of walkable street intersections measured within a one kilometer network buffer (equal to: 26.95303)

Office Building Use Mix

Measures the distribution of office sector building square feet within a one-kilometer grid-cell buffer. Is only measured when both total building square feet and office building square feet have values above zero within a one kilometer buffer of the study area geography. Meaningful only as an input to the overall building use equation.

Equation 11-2: Office Building Use Mix

$$BEO_{um} = \left(\left(\frac{BEO_{sf1km}}{B_{sf1km}}\right) * ln\left(\frac{BEO_{sf1km}}{B_{sf1km}}\right)\right)$$

where:

BEO_{um} = **bldg_use_mix_office:** Office building use mix index

BEO_{sf1km} = **bldg_sqft_office_onekm:** Office building square feet within one kilometer

B_{sf1km} = **bldg_sqft_total_onekm:** Total building square feet within one kilometer

Service Building Use Mix

Measures the distribution of service sector building square feet within a one-kilometer grid-cell buffer. Is only measured when total building square feet, public building square feet and education building square feet have values above zero within a one kilometer buffer of the study area geography. Meaningful only as an input to the overall building use equation.

Equation 11-3: Service Building Use Mix

$$BES_{um} = \left(\left(\frac{BEE_{sf1km} + BEP_{sf1km}}{B_{sf1km}}\right) * ln\left(\frac{BEE_{sf1km} + BEP_{sf1km}}{B_{sf1km}}\right)\right)$$

where:

BES_{um} = **bldg_use_mix_service:** Service building use mix index

BEE_{sf1km} = **bldg_sqft_educ_onekm:** Education building square feet within one kilometer

BEP_{sf1km} = **bldg_sqft_public_onekm:** Public building square feet within one kilometer

B_{sf1km} = **bldg_sqft_total_onekm:** Total building square feet within one kilometer

Retail Building Use Mix

Measures the distribution of retail sector building square feet within a one-kilometer grid-cell buffer. Is only measured when both total building square feet and retail sector building square feet have values above zero within a one kilometer buffer of the study area geography. Meaningful only as an input to the overall building use equation.

Equation 11-4: Retail Building Use Mix

$$BER_{um} = \left(\left(\frac{BER_{sf1km} + BERA_{sf1km} + BEER_{sf1km}}{B_{sf1km}}\right) * ln\left(\frac{BEO_{sf1km} + BERA_{sf1km} + BEER_{sf1km}}{B_{sf1km}}\right)\right)$$

where:

BER_{um} = **bldg_use_mix_retail:** Retail building use mix index

BER_{sf1km} = **bldg_sqft_retail_onekm:** Retail building square feet within one kilometer

$BERA_{sf1km}$ = **bldg_sqft_restaccom_onekm:** Restaurant and accommodation building square feet within one kilometer

$BEER_{sf1km}$ = **bldg_sqft_entrec_onekm:** Entertainment and recreation building square feet within one kilometer

B_{sf1km} = **bldg_sqft_total_onekm:** Total building square feet within one kilometer

Residential Building Use Mix

Residential building use mix measures the distribution of residential building square feet within a one-kilometer grid-cell buffer. It is only measured when both total building square feet and residential building square feet have values above zero within a one kilometer buffer of the study area geography. Meaningful only as an input to the overall building use equation.

Equation 11-5: Residential Building Use Mix

$$BR_{um} = \left(\left(\frac{BRSF_{sf1km} + BRTH_{sf1km} + BRMF_{sf1km}}{B_{sf1km}}\right) * ln\left(\frac{BRSF_{sf1km} + BRTH_{sf1km} + BRMF_{sf1km}}{B_{sf1km}}\right)\right)$$

where:

BR_{um} = **bldg_use_mix_residential:** Residential building use mix index

$BRSF_{sf1km}$ = **bldg_sqft_detsf_onekm:** Residential single family detached building square feet within one kilometer

$BRTH_{sf1km}$ = **bldg_sqft_attsf_onekm:** Residential single family attached (town home) building square feet within one kilometer

$BRMF_{sf1km}$ = **bldg_sqft_mf_onekm:** Residential multifamily building square feet within one kilometer

B_{sf1km} = **bldg_sqft_total_onekm:** Total building square feet within one kilometer

Building Use Mix

Building use mix measures the evenness of the distribution of residential, retail, office, and service sector building floor area square feet within a one-kilometer grid-cell buffer. This index is calculated based on four subsidiary indices for office, service, retail and residential use mixes. A single use will result in a low mix of 0.0, whereas an equal balance of all land uses will result in a high entropy of 1.0. High land use mix typically indicates an ability to travel to multiple destinations within close proximity, which is critical for efficient pedestrian, cyclist and transit travel.

Equation 11-6: Building Use Mix

$$B_{um} = \left(\frac{BEO_{um} + BES_{um} + BER_{um} + BR_{um}}{-\ln(4)}\right)$$

where:

B_{um} = **bldg_use_mix:** Building use mix index

BEO_{um} = **bldg_use_mix_office:** Amount of office building use mix

BES_{um} = **bldg_use_mix_service:** Residential use density of dwelling units within one kilometer

BER_{um} = **bldg_use_mix_retail:** Residential use density of dwelling units within one kilometer

BR_{um} = **bldg_use_mix_residential:** Residential use density of dwelling units within one kilometer

Dwelling Unit Density

Dwelling unit density measures the density of residential dwelling units within a one-kilometer grid-cell buffer. It is only calculated when residential + mixed use parcel acres as well as total dwelling units are all above zero within a one-kilometer buffer of the study area geography; in this case, the natural logarithm of dwelling unit density is also produced, which is used in the car time model.

Equation 11-7: Dwelling Unit Density

$$DU_{ac1km} = \left(\frac{DU_{1km}}{(PR_{ac1km} + PMU_{ac1km})}\right)$$

where:

DU_{ac1km} = **use_du_dens_onekm:** Residential use density within one kilometer

DU_{1km} = **du_onekm:** Dwelling units within one kilometer

PR_{ac1km} = **acres_parcel_res_onekm:** Acres of residential parcels within one kilometer

PMU_{ac1km} = **acres_parcel_mixed_onekm:** Acres of mixed use (residential + employment) parcels within one kilometer

Equation 11-8: Natural Logarithm of Dwelling Unit Density

$$\ln(DU_{ac1km}) = ln\left(\frac{DU_{1km}}{(PR_{ac1km} + PMU_{ac1km})}\right)$$

where:

$ln(DU_{ac1km})$ = **use_du_dens_onekm_ln:** Natural logarithm of residential use density within one kilometer

DU_{1km} = **du_onekm:** Dwelling units within one kilometer

PR_{ac1km} = **acres_parcel_res_onekm:** Acres of residential parcels within one kilometer

PMU_{ac1km} = **acres_parcel_mixed_onekm:** Acres of mixed use (residential + employment) parcels within one kilometer

Network-Based Intersection Counts and Density

Network-based intersection counts and density measure the count of walkable street intersections within a one-kilometer grid-cell buffer, rounds this value to the nearest whole number, then uses a lookup table to derive from this the network-based walkable street intersection count and density. Because UrbanFootprint uses airline buffers to count intersection and the NQLS intersection were counted within smaller network buffers, this look-up table is needed to translate the UrbanFootprint intersection count to a network buffer equivalent. The lookup table was populated through an analysis of the relationships between intersection counts in airline buffers versus network buffers using NQLS and SANDAG data.

Table 11-1: Walkable Street Intersections Crow-Fly to Network Buffer Lookup Table (excerpt, whole table contains values for 0 to 1,000)

intersection_ count_onekm	intersection_count_ onekm_network	intersection_buffer_ onekm_network	intersection_density_ sqkm_network
1	0.553690875	0.31709064	1.74615963
2	1.099086554	0.32534628	3.378205381
3	1.636370623	0.33360192	4.905159489
4	2.16572534	0.34185756	6.335168777
5	2.687331631	0.3501132	7.675607864
6	3.201369095	0.35836884	8.933168114

7	3.708015999	0.36662448	10.11393456
8	4.207449283	0.37488012	11.22345267
9	4.699844556	0.38313576	12.26678647
10	5.1853761	0.3913914	13.24856933

Household Income Categories Ranking Mean

Though UrbanFootprint natively classifies household income into at least twelve disaggregate income categories, these are collapsed into 2- and 3-category variables to improve the fit of some of the health models. The inputs to this process are UrbanFootprint's native income categories.

Equation 11-9: Household Income 2-Category Ranking Mean

$$\begin{aligned}\mathrm{HHI}_{2catmn} = \Big(\Big(\big(&HHI_{0-10kpct} + HHI_{10-20kpct} + HHI_{20-30kpct} + HHI_{30-40kpct}\big) * 1\Big) \\ &+ \Big(\big(HHI_{40-50kpct} + HHI_{50-60kpct} + HHI_{60-75kpct} + HHI_{75-100kpct} \\ &+ HHI_{100-125kpct} + HHI_{125-150kpct} + HHI_{150-200kpct} + HHI_{200kppct}\big) * 2\Big)\Big)\end{aligned}$$

where:

HHI_{2catmn} = **bg_ph_hh_inc_2cat_mean:** Two-category ranking mean of household income at the block group level for the public health engine

$HHI_{0\text{-}10kpct}$ = **bg_hh_inc00_10_pct:** The percent of all households (in a block group) with annual household income between $0 and $10,000

$HHI_{10\text{-}20kpct}$ = **bg_hh_inc10_20_pct:** The percent of all households (in a block group) with annual household income between $10,000 and $20,000

$HHI_{20\text{-}30kpct}$ = **bg_hh_inc20_30_pct:** The percent of all households (in a block group) with annual household income between $20,000 and $30,000

$HHI_{30\text{-}40kpct}$ = **bg_hh_inc30_40_pct:** The percent of all households (in a block group) with annual household income between $30,000 and $40,000

$HHI_{40\text{-}50kpct}$ = **bg_hh_inc40_50_pct:** The percent of all households (in a block group) with annual household income between $40,000 and $50,000

$HHI_{50\text{-}60kpct}$ = **bg_hh_inc50_60_pct:** The percent of all households (in a block group) with annual household income between $50,000 and $60,000

$HHI_{60\text{-}75kpct}$ = **bg_hh_inc60_75_pct:** The percent of all households (in a block group) with annual household income between $60,000 and $75,000

$HHI_{75\text{-}100kpct}$ = **bg_hh_inc75_100_pct:** The percent of all households (in a block group) with annual household income between $75,000 and $100,000

$HHI_{100\text{-}125kpct}$= **bg_hh_inc100_125_pct:** The percent of all households (in a block group) with annual household income between $100,000 and $125,000

$HHI_{125\text{-}150kpct}$= **bg_hh_inc125_150_pct:** The percent of all households (in a block group) with annual household income between $125,000 and $150,000

$HHI_{150\text{-}200kpct}$= **bg_hh_inc150_200_pct:** The percent of all households (in a block group) with annual household income between $150,000 and $200,000

$HHI_{200kppct}$ = **bg_hh_inc200p_pct:** The percent of all households (in a block group) with annual household income above $200,000

Equation 11-10: Household Income 3-Category Ranking Mean

$$\mathrm{HHI}_{3catmn} = \Big(\big((HHI_{0-10kpct} + HHI_{10-20kpct} + HHI_{20-30kpct}) * 1\big) + \big((HHI_{30-40kpct} + HHI_{40-50kpct} + HHI_{50-60kpct} + HHI_{60-75kpct}) * 2\big) + ((HHI_{75-100kpct} + HHI_{100-125kpct} + HHI_{125-150kpct} + HHI_{150-200kpct} + HHI_{200kppct}) * 3\Big)$$

where:

HHI_{3catmn} = **bg_ph_hh_inc_3cat_mean:** Three-category ranking mean of household income at the block group level for the public health engine

$HHI_{0-10kpct}$ = **bg_hh_inc00_10_pct:** The percent of all households (in a block group) with annual household income between $0 and $10,000

$HHI_{10-20kpct}$ = **bg_hh_inc10_20_pct:** The percent of all households (in a block group) with annual household income between $10,000 and $20,000

$HHI_{20-30kpct}$ = **bg_hh_inc20_30_pct:** The percent of all households (in a block group) with annual household income between $20,000 and $30,000

$HHI_{30-40kpct}$ = **bg_hh_inc30_40_pct:** The percent of all households (in a block group) with annual household income between $30,000 and $40,000

$HHI_{40-50kpct}$ = **bg_hh_inc40_50_pct:** The percent of all households (in a block group) with annual household income between $40,000 and $50,000

$HHI_{50-60kpct}$ = **bg_hh_inc50_60_pct:** The percent of all households (in a block group) with annual household income between $50,000 and $60,000

$HHI_{60-75kpct}$ = **bg_hh_inc60_75_pct:** The percent of all households (in a block group) with annual household income between $60,000 and $75,000

$HHI_{75-100kpct}$ = **bg_hh_inc75_100_pct:** The percent of all households (in a block group) with annual household income between $75,000 and $100,000

$HHI_{100-125kpct}$ = **bg_hh_inc100_125_pct:** The percent of all households (in a block group) with annual household income between $100,000 and $125,000

$HHI_{125-150kpct}$ = **bg_hh_inc125_150_pct:** The percent of all households (in a block group) with annual household income between $125,000 and $150,000

$HHI_{150-200kpct}$ = **bg_hh_inc150_200_pct:** The percent of all households (in a block group) with annual household income between $150,000 and $200,000

$HHI_{200kppct}$ = **bg_hh_inc200p_pct:** The percent of all households (in a block group) with annual household income above $200,000

Educational Attainment Categories Ranking Mean

Though UrbanFootprint natively classifies educational attainment into five categories, these are normalized to improve the fit of some of the health models. The inputs to this process are UrbanFootprint's native educational attainment categories.

Equation 11-11: Educational Attainment Normalization for High School Not Completed

$$\mathrm{ED}_{nohspctnorm} = \left(ED_{nohspct} * \left(\frac{1}{ED_{nohspct} + ED_{hspct} + ED_{asspct} + ED_{bachpct} + ED_{gradpct}} \right) \right)$$

where:

$ED_{nohspctnorm}$ = **normalized_bg_pop_hs_not_comp_pct:** Normalized percentage of all adult population (within a block group) that had not completed a high school education as of the most recent Census

$ED_{nohspct}$ = **bg_pop_hs_not_comp_pct:** Percentage of all adult population (within a block group) that had not completed a high school education as of the most recent Census

ED_{hspct} = **bg_pop_hs_diploma_pct:** Percentage of all adult population (within a block group) that had completed a high school diploma (or equivalent) as of the most recent Census

ED_{asspct} = **bg_pop_assoc_some_coll_pct:** Percentage of all adult population (within a block group) with an associate's degree or some other level of college education not yet including a bachelor's degree as of the most recent Census

$ED_{bachpct}$ = **bg_pop_coll_degree_pct:** Percentage of all adult population (within a block group) that had received a bachelor's degree as of the most recent Census

$ED_{gradpct}$ = **bg_pop_grad_degree_pct:** Percentage of all adult population (within a block group) that had received a graduate school degree as of the most recent Census

Equation 11-12: Educational Attainment Normalization for High School Diploma

$$\mathrm{ED}_{hspctnorm} = \left(ED_{hspct} * \left(\frac{1}{ED_{nohspct} + ED_{hspct} + ED_{asspct} + ED_{bachpct} + ED_{gradpct}} \right) \right)$$

where:

$ED_{hspctnorm}$ = **normalized_bg_pop_hs_diploma_pct:** Normalized percentage of all adult population (within a block group) that had received a high school diploma (or equivalent) as of the most recent Census

$ED_{nohspct}$ = **bg_pop_hs_not_comp_pct:** Percentage of all adult population (within a block group) that had not completed a high school education as of the most recent Census

ED_{hspct} = **bg_pop_hs_diploma_pct:** Percentage of all adult population (within a block group) that had completed a high school diploma (or equivalent) as of the most recent Census

ED_{asspct} = **bg_pop_assoc_some_coll_pct:** Percentage of all adult population (within a block group) with an associate's degree or some other level of college education not yet including a bachelor's degree as of the most recent Census

$ED_{bachpct}$ = **bg_pop_coll_degree_pct:** Percentage of all adult population (within a block group) that had received a bachelor's degree as of the most recent Census

$ED_{gradpct}$ = **bg_pop_grad_degree_pct:** Percentage of all adult population (within a block group) that had received a graduate school degree as of the most recent Census

Equation 11-13: Educational Attainment Normalization for Associate's Degree / Some College

$$\mathrm{ED}_{asspctnorm} = \left(ED_{asspct} * \left(\frac{1}{ED_{nohspct} + ED_{hspct} + ED_{asspct} + ED_{bachpct} + ED_{gradpct}} \right) \right)$$

where:

$ED_{asspctnorm}$ = **normalized_bg_pop_assoc_some_coll_pct:** Normalized percentage of all adult population (within a block group) with an associate's degree or some other level of college education not yet including a bachelor's degree as of the most recent Census

$ED_{nohspct}$ = **bg_pop_hs_not_comp_pct:** Percentage of all adult population (within a block group) that had not completed a high school education as of the most recent Census

ED_{hspct} = **bg_pop_hs_diploma_pct:** Percentage of all adult population (within a block group) that had completed a high school diploma (or equivalent) as of the most recent Census

ED_{asspct} = **bg_pop_assoc_some_coll_pct:** Percentage of all adult population (within a block group) with an associate's degree or some other level of college education not yet including a bachelor's degree as of the most recent Census

$ED_{bachpct}$ = **bg_pop_coll_degree_pct:** Percentage of all adult population (within a block group) that had received a bachelor's degree as of the most recent Census

$ED_{gradpct}$ = **bg_pop_grad_degree_pct:** Percentage of all adult population (within a block group) that had received a graduate school degree as of the most recent Census

Equation 11-14: Educational Attainment Normalization for College Bachelor's Degree

$$\mathrm{ED}_{bachpctnorm} = \left(ED_{bachpct} * \left(\frac{1}{ED_{nohspct} + ED_{hspct} + ED_{asspct} + ED_{bachpct} + ED_{gradpct}}\right) \right)$$

where:

$ED_{bachpctnorm}$ = **normalized_bg_pop_coll_degree_pct:** Normalized percentage of all adult population (within a block group) that had received a bachelor's degree as of the most recent Census

$ED_{nohspct}$ = **bg_pop_hs_not_comp_pct:** Percentage of all adult population (within a block group) that had not completed a high school education as of the most recent Census

ED_{hspct} = **bg_pop_hs_diploma_pct:** Percentage of all adult population (within a block group) that had completed a high school diploma (or equivalent) as of the most recent Census

ED_{asspct} = **bg_pop_assoc_some_coll_pct:** Percentage of all adult population (within a block group) with an associate's degree or some other level of college education not yet including a bachelor's degree as of the most recent Census

$ED_{bachpct}$ = **bg_pop_coll_degree_pct:** Percentage of all adult population (within a block group) that had received a bachelor's degree as of the most recent Census

$ED_{gradpct}$ = **bg_pop_grad_degree_pct:** Percentage of all adult population (within a block group) that had received a graduate school degree as of the most recent Census

Equation 11-15: Educational Attainment Normalization for Graduate Degree

$$\mathrm{ED}_{gradpctnorm} = \left(ED_{gradpct} * \left(\frac{1}{ED_{nohspct} + ED_{hspct} + ED_{asspct} + ED_{bachpct} + ED_{gradpct}}\right) \right)$$

where:

$ED_{gradpctnorm}$ = **normalized_bg_pop_grad_degree_pct:** Normalized percentage of all adult population (within a block group) that had received a graduate school degree as of the most recent Census

$ED_{nohspct}$ = **bg_pop_hs_not_comp_pct:** Percentage of all adult population (within a block group) that had not completed a high school education as of the most recent Census

ED_{hspct} = **bg_pop_hs_diploma_pct:** Percentage of all adult population (within a block group) that had completed a high school diploma (or equivalent) as of the most recent Census

ED_{asspct} = **bg_pop_assoc_some_coll_pct:** Percentage of all adult population (within a block group) with an associate's degree or some other level of college education not yet including a bachelor's degree as of the most recent Census

$ED_{bachpct}$ = **bg_pop_coll_degree_pct:** Percentage of all adult population (within a block group) that had received a bachelor's degree as of the most recent Census

$ED_{gradpct}$ = **bg_pop_grad_degree_pct:** Percentage of all adult population (within a block group) that had received a graduate school degree as of the most recent Census

Primary Metrics: Weight- and Activity-Related Regression Models

The regression models were built using UD4H data from King County (Seattle), Washington and the Atlanta, Georgia region. These two data sources are described in Table 11-2.

Table 11-2: Overview of data sourced from previous UD4H studies

Data source	Sample	Built environment inputs	Spatial unit for built environment analysis	Demographic/ socioeconomic inputs	Health outcomes
King County Neighborhood Quality of Life Study (NQLS)	1,228 adults	Walkability (composed of land use mix, street connectivity, net residential density, and floor-to-area ratio)	1-kilometer buffer of respondent's home	Gender, age, education, ethnicity, number of children under 18, household income, vehicle ownership	BMI, objectively measured levels of moderate/ vigorous physical activity, depressive symptoms, social cohesion
SMARTRAQ Atlanta Regional Commission Household Travel Survey	16,873 participants 5 years or older	Walkability (composed of land use mix, street connectivity, net residential density)	1-kilometer buffer of respondent's home	Gender, age, education, ethnicity, number of children under 18, household income, vehicle ownership	BMI, transportation-related physical activity, time spent in automobiles, social cohesion

Adapting regression models from non-California locations assumes the following:

- That the relationships between each independent variable and the predictor are similar in both locations (e.g. people in California behave similarly in their built environments as would the identical people in Atlanta)
- Health outcomes depend not only on built environment variables but also on demographic/socioeconomic variables (e.g. low-income households have different travel behaviors than high-income households). With adapted models, it is assumed not only that the relationships

between each independent variable and the predictor are similar in both locations, but also that the populations themselves share similar demographic/socioeconomic characteristics.

Primary data inputs for these four models include both measures of the built environment (intersection, retail floor area, and dwelling unit densities as well as building use mix) and demographics (gender, age, household income, size, and auto ownership, and level of educational attainment). For public health modeling, future demographic variables were held constant with the base/existing conditions year rates for each grid cell, calculated using US Census 2010; this is intended to isolate the effect of land use on public health.

Primary Metrics: Formulas for Weight and Activity Related Models

Predictions of weight and activity levels are produced at the grid-cell level using the outcomes of the intermediate models:

- ***Minutes of Daily Adult Moderate/Vigorous Physical Activity***. A prediction of daily minutes of moderate/vigorous physical activity (MVPA) for adults 18 and older
- ***Adult Body Mass Index***. A prediction of body mass index (BMI) for adults 18 and older.
- ***Percent of Adults Overweight or Obese***. A prediction of the percent of adults 18 and older that would be categorized as overweight or obese (BMI > 25).
- ***Percent of Adults Obese***. A prediction of the percent of adults 18 and older that would be categorized as obese (BMI > 30).
- ***Daily Adult Time Spent in Cars***. A prediction of daily minutes of time spent in cars for persons 16 and older.

These then become indicators of and inputs to predictions of health outcomes and fiscal impacts.

Daily Adult Moderate/Vigorous Physical Activity

The following model predicts daily minutes of moderate/vigorous physical activity (MVPA) for adults 18 and older, based on objectively-measured data collected through accelerometer devices. The walkability index (composed of intersection density, residential density, retail FAR, and land use mix) was found to be a significant predictor of MVPA in a previously published NQLS article.[56] The UD4H data show that after adjusting for race, sex, age, household size, education, and income, a 10-minute increase in daily minutes of moderate/vigorous physical activity was associated with a 0.61-point decrease in BMI**.** This was determined by building a regression model using the NQLS data to predict BMI with MVPA after controlling for individual and household covariates. The model indicates that higher MVPA is associated with being male, younger, having a higher education, living in a household with higher income, larger size, and fewer vehicles, and living in a neighborhood with higher residential density and retail floor:area ratio.

[56] Sallis JF, Saelens BE, Frank LD, et al. Neighborhood built environment and income: Examining multiple health outcomes. *Social Science & Medicine*. 2009;68(7):1285-93.

Equation 11-16: Daily Adult Moderate and Vigorous Physical Activity

$$\mathrm{MVPA}_d = (exp\big(MVPA_{co\_int} + \big(PM_{20\_64pct} * PM_{mco\_20\_64pct}\big) + \big(PA_{20\_64avg} * PA_{mco\_20\_64avg}\big) + \big(ED_{mean} * ED_{mco\_mean}\big) + \big(HHI_{2cm} * HHI_{mco\_2cm}\big) + \big(HH_{avg\_sz} * HH_{mco\_avg\_sz}\big) + \big(HH_{avg\_v} * HH_{mco\_avg\_v}\big) + \big(DU_{ac1km} * DU_{mco\_ac1km}\big) + (BER_{far1km} * BER_{mco\_far1km})) * MVPA_{mult}\big)$$

where:

$MVPA_d$	=	**avg_mvpa:** Average daily adult minutes of moderate and/or vigorous physical activity
$MVPA_{co\_int}$	=	**mvpa_coef_intercept:** MVPA coefficient intercept (equal to: 2.964257857)
PM_{20_64pct}	=	**pop_male_of_age20_64_pct:** The proportion of the adult population that is male
$PM_{mco\_20\_64pct}$	=	**mvpa_coef_pop_male_of_age20_64_pct:** The MVPA coefficient of the adult population that is male (equal to: 0.305229256)
PA_{20_64avg}	=	**pop_avg_age_of20_64:** The average age of the population who are between the ages of 20 and 64
$PA_{mco\_20\_64avg}$	=	**mvpa_coef_pop_avg_age_of20_64:** The MVPA coefficient of the average age of the population who are between the ages of 20 and 64 (equal to: -0.010988987)
ED_{mean}	=	**ph_pop_ed_comp_mean:** The mean of the four educational attainment categories
ED_{mco_mean}	=	**mvpa_coef_pop_ed_comp_mean:** The MVPA coefficient of the mean of the four educational attainment categories (equal to: 0.083969788)
HHI_{2cm}	=	**ph_hh_inc_2cat_mean:** The mean of the household income two-category ranking mean
HHI_{mco_2cm}	=	**mvpa_coef_hh_inc_2cat_mean:** The MVPA coefficient of the mean of the household income two-category ranking mean (equal to: 0.157678829)
HH_{avg_sz}	=	**hh_avg_size:** The average number of people per household
$HH_{mco\_avg\_sz}$	=	**mvpa_coef_hh_avg_size:** The MVPA coefficient of the average number of people per household (equal to: 0.024185665)
HH_{avg_v}	=	**hh_avg_veh:** The average number of vehicles per household
$HH_{mco\_avg\_v}$	=	**mvpa_coef_hh_avg_veh:** The MVPA coefficient of the average number of vehicles per household (equal to: -0.04746467)
DU_{ac1km}	=	**use_du_dens_onekm:** The number of dwelling units per residential and mixed use parcel acres within one kilometer
DU_{mco_ac1km}	=	**mvpa_coef_use_du_dens_onekm:** The MVPA coefficient of the number of dwelling units per residential and mixed use parcel acres within one kilometer (equal to: 0.003833926)
BER_{far1km}	=	**retail_use_far_onekm:** The retail building floor area ratio within one kilometer
BER_{mco_far1km}	=	**mvpa_coef_retail_use_far_onekm:** The MVPA coefficient of the retail building floor area ratio within one kilometer (equal to: 0.326918767387217)
$MVPA_{mult}$	=	**mvpa_multiplier:** The MVPA multiplier (equal to: 1.230668), used to correct for retransformation bias when predicting a log-transformed outcome.

Adult Body Mass Index (BMI)

The following model is designed to predict body mass index (BMI) for adults 18 and older. Participating in higher levels of physical activity is associated with lower BMI, and having a lower BMI reduces the risk for a variety of health outcomes such as cardiovascular disease and diabetes. The walkability index (composed of intersection density, residential density, retail FAR, and land use mix) was found to be a significant predictor of BMI in a previously published NQLS article.[57] The model indicates that lower BMI is associated with being female, younger, having a higher education, living in a household with higher income, and living in a neighborhood with higher residential density and retail floor:area ratio.

Equation 11-17: Average adult body mass index (BMI)

$$\begin{aligned}\mathrm{BMI}_a = (exp\big(&BMI_{co\_int} + \big(PM_{20\_64pct} * PM_{bco\_20\_64pct}\big) + \big(PA_{20\_64avg} * PA_{bco\_20\_64avg}\big)\\ &+ \big(ED_{mean} * ED_{bco\_mean}\big) + \big(HHI_{3cm} * HHI_{bco\_3cm}\big) + \big(DU_{ac1km} * DU_{bco\_ac1km}\big)\\ &+ (BER_{far1km} * BER_{bco\_far1km})) * BMI_{mult}\big)\end{aligned}$$

where:

BMI_a = **avg_bmi:** Average adult body mass index

BMI_{co_int} = **bmi_coef_intercept:** BMI coefficient intercept (equal to: 3.3256265)

PM_{20_64pct} = **pop_male_of_age20_64_pct:** The proportion of the adult population that is male

$PM_{bco\_20\_64pct}$ = **bmi_coef_pop_male_of_age20_64_pct:** The BMI coefficient of the adult population that is male (equal to: 0.029335214)

PA_{20_64avg} = **pop_avg_age_of20_64:** The average age of the population who are between the ages of 20 and 64

$PA_{bco\_20\_64avg}$ = **bmi_coef_pop_avg_age_of20_64:** The BMI coefficient of the average age of the population who are between the ages of 20 and 64 (equal to: 0.002631823)

ED_{mean} = **ph_pop_ed_comp_mean:** The mean of the four educational attainment categories

ED_{bco_mean} = **bmi_coef_pop_ed_comp_mean:** The BMI coefficient of the mean of the four educational attainment categories (equal to: -0.029726726)

HHI_{3cm} = **ph_hh_inc_2cat_mean:** The mean of the household income two-category ranking mean

HHI_{bco_3cm} = **bmi_coef_hh_inc_3cat_mean:** The BMI coefficient of the mean of the household income three-category ranking mean (equal to: -0.037283463)

DU_{ac1km} = **use_du_dens_onekm:** The number of dwelling units per residential and mixed use parcel acres within one kilometer

DU_{bco_ac1km} = **bmi_coef_use_du_dens_onekm:** The BMI coefficient of the number of dwelling units per residential and mixed use parcel acres within one kilometer (equal to: -0.000685699)

BER_{far1km} = **retail_use_far_onekm:** The retail building floor area ratio within one kilometer

BER_{bco_far1km} = **bmi_coef_retail_use_far_onekm:** The BMI coefficient of the retail building floor area ratio within one kilometer (equal to: -0.046475841)

BMI_{mult} = **bmi_multiplier:** The BMI multiplier (equal to: 1.017248), used to correct for retransformation bias when predicting a log-transformed outcome.

[57] Frank LD, Sallis JF, Conway TL, et al. Many Pathways from Land Use to Health. *Journal of the American Planning Association*. 2006;72(1):75-87.

Adult Overweight Plus Obesity Percent

The following model is designed to predict the percent of adults 18 and older that are either overweight or obese (BMI > 25). Being overweight or obese increases the risk for a variety of conditions, such as cardiovascular disease and diabetes. The walkability index (composed of intersection density, residential density, retail FAR, and land use mix) was found to be a significant predictor of being overweight or obese in a previously published NQLS article.[56] The model indicates that a lower likelihood of being overweight or obese is associated with being female, younger, having a higher education, living in a household with higher income, and living in a neighborhood with a higher walkability index.

Equation 11-18: Adult overweight + obese percent.

$$\begin{aligned}\mathrm{OpO}_{pct} = ((&exp\left(OpO_{co_{int}} + \left(PM_{20_{64pct}} * PM_{oco_{20_{64pct}}}\right) + \left(PA_{20_{64avg}} * PA_{oco_{20_{64avg}}}\right)\right.\\ &\left. + \left(ED_{mean} * ED_{oco_{mean}}\right) + \left(HHI_{3cm} * HHI_{oco_{3cm}}\right) + (W_i * W_{oco_i}))\right)/(1\\ &+ exp\left(OpO_{co_{int}} + \left(PM_{20_{64pct}} * PM_{oco_{20_{64pct}}}\right) + \left(PA_{20_{64avg}} * PA_{oco_{20_{64avg}}}\right)\right.\\ &\left. + \left(ED_{mean} * ED_{oco_{mean}}\right) + \left(HHI_{3cm} * HHI_{oco_{3cm}}\right) + (W_i * W_{oco_i}))\right))\end{aligned}$$

where:

OpO_{pct} = **overweight_plus_obesity_pct:** Percent of adults over the age of 18 who are either overweight or obese

OpO_{co_int} = **overweight_coef_intercept:** The overweight + obese coefficient intercept (equal to: -0.12257963)

PM_{20_64pct} = **pop_male_of_age20_64_pct:** The proportion of the adult population that is male

$PM_{oco\_20\_64pct}$ = **overweight_coef_pop_male_of_age20_64_pct:** The overweight + obese coefficient of the adult population that is male (equal to: 0.654012971)

PA_{20_64avg} = **pop_avg_age_of20_64:** The average age of the population who are between the ages of 20 and 64

$PA_{oco\_20\_64avg}$ = **overweight_coef_pop_avg_age_of20_64:** The overweight + obese coefficient of the average age of the population who are between the ages of 20 and 64 (equal to: 0.027253615)

ED_{mean} = **ph_pop_ed_comp_mean:** The mean of the four educational attainment categories

ED_{oco_mean} = **overweight_coef_pop_ed_comp_mean:** The overweight + obese coefficient of the mean of the four educational attainment categories (equal to: -0.316779213)

HHI_{3cm} = **ph_hh_inc_3cat_mean:** The mean of the household income three-category ranking mean

HHI_{oco_3cm} = **overweight_coef_hh_inc_3cat_mean:** The overweight + obese coefficient of the mean of the household income three-category ranking mean (equal to: -0.183311868)

W_i = **ph_walkability_idx:** Walkability index for the public health module

W_{oco_i} = **overweight_coef_walkability_idx:** The overweight + obese coefficient of the walkability index for the public health module (equal to: -0.074130817)

Adult Obesity Percent

The following model is designed to predict the percent of adults 18 and older that are obese (BMI > 30). Being obese increases the risk for a variety of conditions, such as cardiovascular disease and diabetes. The walkability index (composed of intersection density, residential density, retail FAR, and land use mix) was found to be a significant predictor of being overweight or obese in a previously published NQLS article.[56] The model indicates that a lower likelihood of being overweight or obese is associated with being male, younger, having a higher education, living in a household with higher income, and living in a neighborhood with a higher walkability index.

Equation 11-19: Adult obesity percent

$$\begin{aligned}\mathrm{OB}_{pct} = ((exp\Big(&OB_{co_{int}} + \Big(PM_{20_{64pct}} * PM_{obco_{20_{64pct}}}\Big) + \Big(PA_{20_{64avg}} * PA_{obco_{20_{64avg}}}\Big) \\ &+ \left(ED_{mean} * ED_{obco_{mean}}\right) + \left(HHI_{3cm} * HHI_{obco_{3cm}}\right) + (W_i * W_{obco_i}))\Big)/(1 \\ &+ exp\Big(OB_{co_{int}} + \Big(PM_{20_{64pct}} * PM_{obco_{20_{64pct}}}\Big) + \Big(PA_{20_{64avg}} * PA_{obco_{20_{64avg}}}\Big) \\ &+ \left(ED_{mean} * ED_{obco_{mean}}\right) + \left(HHI_{3cm} * HHI_{obco_{3cm}}\right) + (W_i * W_{obco_i}))\Big))\end{aligned}$$

where:

OB_{pct} = **obesity_pct:** Percent of adults over the age of 18 who are obese

OB_{co_int} = **obesity_coef_intercept:** The obesity coefficient intercept (equal to: -0.292108373808172000)

PM_{20_64pct} = **pop_male_of_age20_64_pct:** The proportion of the adult population that is male

$PM_{obco\_20\_64pct}$= **obesity_coef_pop_male_of_age20_64_pct:** The obesity coefficient of the adult population that is male (equal to: -0.200740183)

PA_{20_64avg} = **pop_avg_age_of20_64:** The average age of the population who are between the ages of 20 and 64

$PA_{obco\_20\_64avg}$ = **obesity_coef_pop_avg_age_of20_64:** The obesity coefficient of the average age of the population who are between the ages of 20 and 64 (equal to: 0.0177412)

ED_{mean} = **ph_pop_ed_comp_mean:** The mean of the four educational attainment categories

ED_{obco_mean} = **obesity_coef_pop_ed_comp_mean:** The obesity coefficient of the mean of the four educational attainment categories (equal to: -0.376193822)

HHI_{3cm} = **ph_hh_inc_2cat_mean:** The mean of the household income two-category ranking mean

HHI_{obco_3cm} = **obesity_coef_hh_inc_3cat_mean:** The obesity coefficient of the mean of the household income three-category ranking mean (equal to: -0.422609299)

W_i = **ph_walkability_idx:** Walkability index for the public health module

W_{obco_i} = **obesity_coef_walkability_idx:** The obesity coefficient of the walkability index for the public health module (equal to: -0.09973074)

Daily Adult Time Spent In Cars

The following model is designed to predict daily minutes of time spent in cars for those persons 16 and older. The same data were used to identify an association between time spent in cars and BMI, published in the American Journal of Preventive Medicine in 2004.[58] An association between time spent in cars and neighborhood social connectedness has also been published.[59] The UD4H data show that after adjusting for race, sex, age, household size, education, and income, a 60 minute increase in daily time spent in a car was associated with a 0.23 point increase in BMI. In this model, the education and income variables are considered as categorical variables rather than continuous variables (as doing so improved the predictive ability of the model), meaning that each category is assigned a unique coefficient. The model indicates that less time spent in cars is associated with being female, older, having a lower education, living in a household with a lower income, larger size, and fewer vehicles, and living in a neighborhood with a higher intersection count, residential density, and land use mix.

Equation 11-20: Daily time spent in cars by persons age 16 or over

$$\begin{aligned}
\mathrm{CT}_{avg} = ((exp\Bigg(& CT_{co_{int}} + \left(\left(PF_{20_{64pct}} + 1\right) * PF_{ctco_{20_{64pct}}}\right) + \left(PA_{20_{64avg}} * PA_{ctco_{20_{64avg}}}\right) \\
&+ \left(ED_{nohspctnorm} * ED_{ctco_{nohspctnorm}}\right) + \left(ED_{hspctnorm} * ED_{ctco_{hspctnorm}}\right) \\
&+ \left(ED_{asspctnorm} * ED_{ctco_{asspctnorm}}\right) + \left(ED_{bachpctnorm} * ED_{ctco_{bachpctnorm}}\right) \\
&+ \left(ED_{gradpctnorm} * ED_{ctco_{gradpctnorm}}\right) + \left(HHI_{0_{10kpct}} * HHI_{ctco_{0_{10kpct}}}\right) \\
&+ \left(HHI_{10_{20kpct}} * HHI_{ctco_{10_{20kpct}}}\right) + \left(HHI_{20_{30kpct}} * HHI_{ctco_{20_{30kpct}}}\right) \\
&+ \left(HHI_{30_{75kpct}} * HHI_{ctco_{30_{75kpct}}}\right) + \left(HHI_{75pkpct} * HHI_{ctco_{75pkpct}}\right) \\
&+ \left(HHI_{avg_{sz}} * HHI_{ctco_{avg_{sz}}}\right) + \left(HHI_{avg_{v}} * HHI_{ctco_{avg_{v}}}\right) \\
&+ \left(\ln(DU_{ac1km}) * DU_{ctco_ac1km_ln}\right) + \left(IC_{sqkmn} * IC_{ctco_{sqkmn}}\right) + \left(\left(B_{um}{}^{2}\right) * B_{ctco_{um}}\right)\Bigg) \\
&- 1) * CT_{mult}\Bigg)
\end{aligned}$$

where:

CT_{avg} = **avg_cartime:** Average daily minutes of time spent by persons age 16 or over in cars

CT_{co_int} = **cartime_coef_intercept:** The car time coefficient intercept (equal to: 2.77906495523088)

PF_{20_64pct} = **pop_female_of_age20_64_pct:** The proportion of the adult population that is female

$PF_{ctco\_20\_64pct}$= **cartime_coef_pop_female_of_age20_64_pct_plus1:** The car time coefficient of the adult population that is female (equal to: -0.0498295633943173)

[58] Frank LD, Andresen M a, Schmid TL. Obesity relationships with community design, physical activity, and time spent in cars. *American journal of preventive medicine*. 2004;27(2):87-96.

[59] Freeman L. The Effects of Sprawl on Neighborhood Social Ties: An Explanatory Analysis. *Journal of the American Planning Association*. 2001;67(1):69-77.

PA_{20_64avg} = **pop_avg_age_of20_64:** The average age of the population who are between the ages of 25 and 64

$PA_{ctco\_20\_64avg}$ = **cartime_coef_pop_avg_age_of20_64:** The car time coefficient of the average age of the population who are between the ages of 25 and 64 (equal to: -0.0125296766474867)

$ED_{nohspctnorm}$ = **normalized_bg_pop_hs_not_comp_pct:** Normalized percentage of all adult population (within a block group) that had not completed a high school education as of the most recent Census

$ED_{ctco\_nohspctnorm}$= **cartime_coef_normalized_bg_pop_hs_not_comp_pct:** The car time coefficient of the normalized percentage of all adult population (within a block group) that had not completed a high school education as of the most recent Census (equal to: 0)

$ED_{hspctnorm}$ = **normalized_bg_pop_hs_diploma_pct:** Normalized percentage of all adult population (within a block group) that had received a high school diploma (or equivalent) as of the most recent Census

$ED_{ctco\_hspctnorm}$= **cartime_coef_normalized_bg_pop_hs_diploma_pct:** The car time coefficient of the normalized percentage of all adult population (within a block group) that had received a high school diploma (or equivalent) as of the most recent Census (equal to: 0.564506021953312)

$ED_{asspctnorm}$ = **normalized_bg_pop_assoc_some_coll_pct:** Normalized percentage of all adult population (within a block group) with an associate's degree or some other level of college education not yet including a bachelor's degree as of the most recent Census

$ED_{ctco\_asspctnorm}$= **cartime_coef_normalized_bg_pop_assoc_some_coll_pct:** The car time coefficient of the normalized percentage of all adult population (within a block group) with an associate's degree or some other level of college education not yet including a bachelor's degree as of the most recent Census (equal to: 0.990966494522151)

$ED_{bachpctnorm}$ = **normalized_bg_pop_coll_degree_pct:** Normalized percentage of all adult population (within a block group) that had received a bachelor's degree as of the most recent Census

$ED_{ctco\_bachpctnorm}$= **cartime_coef_normalized_bg_pop_coll_degree_pct:** The car time coefficient of the normalized percentage of all adult population (within a block group) that had received a bachelor's degree as of the most recent Census (equal to: 1.08124652665679)

$ED_{gradpctnorm}$ = **normalized_bg_pop_grad_degree_pct:** Normalized percentage of all adult population (within a block group) that had received a graduate school degree as of the most recent Census

$ED_{ctco\_gradpctnorm}$= **cartime_coef_normalized_bg_pop_grad_degree_pct:** The car time coefficient of the normalized percentage of all adult population (within a block group) that had received a graduate school degree as of the most recent Census (equal to: 1.21042957886447)

$HHI_{0\text{-}10kpct}$ = **bg_hh_inc00_10_pct:** The percent of all households (in a block group) with annual household income between \$0 and \$10,000

$HHI_{ctco\_0\text{-}10kpct}$= **cartime_coef_bg_hh_inc00_10_pct:** The car time coefficient of the percent of all households (in a block group) with annual household income between \$0 and \$10,000 (equal to: 0)

$HHI_{10\text{-}20kpct}$ = **bg_hh_inc10_20_pct:** The percent of all households (in a block group) with annual household income between \$10,000 and \$20,000

$HHI_{ctco\_10\text{-}20kpct}$= **cartime_coef_bg_hh_inc10_20_pct:** The car time coefficient of the percent of all households (in a block group) with annual household income between \$10,000 and \$20,000 (equal to: 0.26347312483403)

$HHI_{20\text{-}30kpct}$ = **bg_hh_inc20_30_pct:** The percent of all households (in a block group) with annual household income between $20,000 and $30,000

$HHI_{ctco\_20\text{-}30kpct}$ = **cartime_coef_bg_hh_inc20_30_pct:** The car time coefficient of the percent of all households (in a block group) with annual household income between $20,000 and $30,000 (equal to: 0.607057619063316)

$HHI_{30\text{-}75kpct}$ = **bg_hh_inc30_75_pct:** The percent of all households (in a block group) with annual household income between $30,000 and $75,000

$HHI_{ctco\_30\text{-}75kpct}$ = **cartime_coef_bg_hh_inc30_75_pct:** The car time coefficient of the percent of all households (in a block group) with annual household income between $30,000 and $75,000 (equal to: 0.884715185837982)

$HHI_{75pkpct}$ = **bg_hh_inc75p_pct:** The percent of all households (in a block group) with annual household income above $75,000

$HHI_{ctco\_75pkpct}$ = **cartime_coef_bg_hh_inc75p_pct:** The car time coefficient of the percent of all households (in a block group) with annual household income above $75,000 (equal to: 0.994771803077393)

HH_{avg_sz} = **hh_avg_size:** The average number of people per household

$HH_{ctco\_avg\_sz}$ = **cartime_coef_hh_avg_size:** The car time coefficient of the average number of people per household (equal to: -0.122644644190441)

HH_{avg_v} = **hh_avg_veh:** The average number of vehicles per household

$HH_{ctco\_avg\_v}$ = **cartime_coef_hh_avg_veh:** The car time coefficient of the average number of vehicles per household (equal to: 0.161569382290239)

$ln(DU_{ac1km})$ = **use_du_dens_onekm_ln:** Natural logarithm of residential use density within one kilometer

$DU_{ctco\_ac1km\_ln}$ = **cartime_coef_use_du_dens_onekm_ln:** The car time coefficient of the natural logarithm of residential use density within one kilometer (equal to: -0.0888741755279524)

IC_{sqkmn} = **intersection_count_onekm_network:** Count of walkable street intersections measured within a one kilometer network buffer

IC_{ctco_sqkmn} = **cartime_coef_intersection_count_onekm_network:** The car time coefficient of the count of walkable street intersections measured within a one kilometer network buffer (equal to: -0.00428453580104705)

B_{um} = **bldg_use_mix:** Building use mix index

B_{ctco_um} = **cartime_coef_bldg_use_mix:** The car time coefficient of the building use mix index (equal to: -0.331507978427603)

CT_{mult} = **cartime_multiplier:** The car time multiplier (equal to: 1.873915) , used to correct for retransformation bias when predicting a log-transformed outcome.

Health Impacts of Obesity/Overweight

As overweight and obesity rates are associated with numerous co-morbid health conditions, these weight metrics formed the basis for a series of post-process models predicting the adult incidence of type II diabetes, hypertension, coronary artery disease, osteoarthritis, chronic back pain, and colorectal and kidney cancer. A meta-analysis published by Guh et al. in 2009 provides incidence rate ratios for overweight and obese adults, stratified by gender, for these co-morbid conditions.[60] Baseline incidence rates for these conditions were identified from a variety of literature sources, calibrated for California using CHIS weight distribution data, and, when possible, validated using CHIS health outcome data.[61,62,63,64,65,66,67,53]

The modeling method is based on the concept of comparative risk assessment, where disease incidence for each future scenario is calculated based on an estimate of baseline incidence, the modeled change in population distribution within three weight categories (normal/underweight, overweight, and obese) between baseline and future scenarios, and the known associations between weight status and health outcomes. A future population with a distribution skewed further towards the obese end of the spectrum is expected to have a greater incidence of obesity-related health conditions, whereas a future population with a distribution skewed further towards the normal end of the spectrum is expected to have a lower incidence of obesity-related health conditions.

Preprocesses for calculation of gender- and population-weighted common odds ratios

The following models pre-calculate the gender- and population-weighted common odds ratios used in the calculations for each specific disease outcome linked to obesity/overweight.

Gender-weighted obesity common odds ratio pre-calculation

The following equation is used to calculate the weighting used for the gender-weighted common odds ratios for all of the diseases predicted based on the change in obesity prevalence. This involves calculating a weighted average to combine the gender-specific rate ratios, based on the California population within each gender category.

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[60] Guh DP, Zhang W, Bansback N, et al. *The incidence of co-morbidities related to obesity and overweight: A systematic review and meta-analysis*. BMC Public Health. 2009; 9: 88.

[61] Centers for Disease Control and Prevention. *Diabetes Data & Trends: California - Rate of New Cases of Diagnosed Diabetes per 1000 Adults, 1996-2009*. Available at: http://apps.nccd.cdc.gov/DDTSTRS/Index.aspx?stateId=6&state=California&cat=prevalence&Data=data&view=Rate&trend=prevalence&id=1&ext=incidence, accessed July 5, 2011.

[62] Dannenburg AL, Garrison RJ, Kannel WB. *Incidence of Hypertension in the Framingham Study*. American Journal of Public Health. 1988; 78: 676-679.

[63] Jones DW, Chambless LE, Folsom AR, et al. *Risk Factors for Coronary Heart Disease in African Americans: The Atherosclerosis Risk in Communities Study, 1987-1997.* Archives of Internal Medicine. 2002; 162: 2565-2571.

[64] Oliveria SA, Felson DT, Reed JI, et al. *Incidence of symptomatic hand, hip, and knee osteoarthritis among patients in a health maintenance organization*. Arthritis and Rheumatism. 1995; 38: 1134-1141.

[65] Hagen KB, Tamos K, Bjerkdal T. *A Prospective Cohort Study of Risk Factors for Disability Retirement Because of Back Pain in the General Working Population*. Health Services Research. 2002; 27: 1790-1796.

[66] National Cancer Institute. Surveillance Epidemiology and End Results Stat Fact Sheets: Colon and Rectum. Available: http://seer.cancer.gov/statfacts/html/colorect.html, accessed July 5, 2011.

[67] National Cancer Institute. Surveillance Epidemiology and End Results Stat Fact Sheets: Kidney and Renal Pelvis. Available: http://seer.cancer.gov/statfacts/html/kidrp.html, accessed July 5, 2011.

Equation 11-21: Gender-based Weighting of Common Odds Ratios for Any Disease based on Obesity Prevalence

$$\mathrm{HI}_{\mathrm{XOBG}_{wor}} = \left(HI_{XOBM\,ior} * \left(\frac{POBM_S}{POBM_S + POBF_S}\right)\right) + \left(HI_{XOBF\,ior} * \left(\frac{POBF_S}{POBM_S + POBF_S}\right)\right)$$

where:

HI_XOBG_{wor} = **[disease *X*]_obese_gender_weighted_odds_ratio:** The pooled gender-weighted odds ratio for disease *X* from literature-based obesity rates

HI_XOBM_{ior} = **[disease *X*]_obese_male_incidence_odds_ratio:** The weighted odds ratio for disease *X* from literature-based obesity rates for males (see Table 11-3 for values)

HI_XOBF_{ior} = **[disease *X*]_obese_female_incidence_odds_ratio:** The weighted odds ratio for disease *X* from literature-based obesity rates for females (see Table 11-3 for values)

$POBM_S$ = **pop_obese_male:** The total statewide obese population that is male (see Table 11-4)

$POBF_S$ = **pop_obese_female:** The total statewide obese population that is female (see Table 11-4)

Gender-weighted overweight common odds ratio pre-calculation

The following equation is used to calculate the weighting used for the gender-weighted common odds ratios for all of the diseases predicted based on the change in overweight prevalence. This involves calculating a weighted average to combine the gender-specific rate ratios, based on the California population within each gender category.

Equation 11-22: Gender-based Weighting of Common Odds Ratios for Any Disease based on Overweight Prevalence

$$\mathrm{HI}_{\mathrm{XOWG}_{wor}} = \left(HI_{XOWM\,ior} * \left(\frac{POWM_S}{POWM_S + POWF_S}\right)\right) + \left(HI_{XOWF\,ior} * \left(\frac{POWF_S}{POWM_S + POWF_S}\right)\right)$$

where:

HI_XOWG_{wor} = **[disease *X*]_overweight_gender_weighted_odds_ratio:** The pooled gender-weighted odds ratio for disease *X* from literature-based overweight rates

HI_XOWM_{ior} = **[disease *X*]_overweight_male_incidence_odds_ratio:** The weighted odds ratio for disease *X* from literature-based overweight rates for males (see Table 11-3 for values)

HI_XOWF_{ior} = **[disease *X*]_overweight_female_incidence_odds_ratio:** The weighted odds ratio for disease *X* from literature-based overweight rates for females (see Table 11-3 for values)

$POWM_S$ = **pop_overweight_male:** The total statewide overweight population that is male (see Table 11-4)

$POWF_S$ = **pop_overweight_female:** The total statewide overweight population that is female (see Table 11-4)

Table 11-3: Gender-Specific Weighted Odds Ratios of Incidences by Disease

	Obese Male Incidence Odds Ratio	Obese Female Incidence Odds Ratio	Overweight Male Incidence Odds Ratio	Overweight Female Incidence Odds Ratio
Diabetes	6.74	12.41	2.4	3.92
Hypertension	1.84	2.42	1.28	1.65
Coronary Artery	1.72	3.1	1.29	1.8

Disease				
Osteoarthritis	4.2	1.96	2.76	1.8
Back Pain	2.81	2.81	1.59	1.59
Colorectal Cancer	1.95	1.66	1.51	1.45
Kidney Cancer	1.82	2.64	1.4	1.82

Population-weighted common odds ratio pre-calculation

The following equation is used to calculate the weighting used for the population-weighted common odds ratios for all of the diseases predicted. This involves calculating a weighted average to combine the obese- and overweight-specific common odds ratios, based on the statewide population within each weight category and the total statewide population.

Equation 11-23: Population-based Weighting of Common Odds Ratios for Any Disease based on Obese + Overweight Common Odds Ratios

$$\mathrm{HI}_{\mathrm{XP}_{wor}} = \frac{\left(\left(HI_{XOBG_{wor}} * POB_S\right) + \left(HI_{XOWG_{wor}} * POW_S\right) + (1 * PN_S)\right)}{PT_S}$$

where:

HI_XP_{wor} = **[disease *X*]_population_weighted_odds_ratio:** The pooled population-weighted odds ratio for disease *X*

HI_XOBG_{wor} = **[disease *X*]_obese_gender_weighted_odds_ratio:** The pooled gender-weighted odds ratio for disease *X* from literature-based obesity rates

HI_XOWG_{wor} = **[disease *X*]_overweight_gender_weighted_odds_ratio:** The pooled gender-weighted odds ratio for disease *X* from literature-based overweight rates

POB_S = **pop_obese:** The total statewide obese population (obese male + obese female; see Table 11-4)

POW_S = **pop_overweight:** The total statewide overweight population (overweight male + overweight female; see Table 11-4)

PN_S = **pop_normal:** The total statewide normal weight population (normal male + normal female; see Table 11-4)

PT_S = **pop_total:** The total statewide population (sum of all values in Table 11-4)

Table 11-4: Distribution of Population in California by Obesity Status (from CHIS, 2009)

	Normal	Overweight	Obese
Male	4,857,000	5,414,000	3,242,000
Female	7,167,000	3,852,000	3,014,000

Type II Diabetes

The following models are designed to predict the common odds ratio of a given member of the population being diagnosed with Type II Diabetes, the change in the common odds ratio, and the overall incidences of Type II Diabetes.

Equation 11-24: Population Common Odds Ratio for Type II Diabetes

$$\text{HISD}_{wor} = ((OB_{pct} * HI_{DOBG_{wor}}) + \left((OpO_{pct} - OB_{pct}) * HI_{DOWG_{wor}}\right) + (1 - OpO_{pct}))$$

where:

$HISD_{wor}$ = **scenario_diabetes_population_weighted_odds_ratio:** Common odds ratio across all three weight status categories that a given member of the population within the analysis geography will be diagnosed with Type II Diabetes, based on the scenario

OB_{pct} = **obesity_pct:** The percent of the scenario population that is obese, based on the results of the results of the adult obesity percent model

HI_DOBG_{wor} = **diabetes_obese_gender_weighted_odds_ratio:** The weighted odds ratio for Type II Diabetes based on gender and obesity (equal to: 9.4716783887468)

OpO_{pct} = **overweight_plus_obesity_pct:** The percent of the scenario population that is overweight + obese, based on the results of the results of the adult overweight/obesity percent model

HI_DOWG_{wor}= **diabetes_overweight_gender_weighted_odds_ratio:** The weighted odds ratio for Type II Diabetes based on gender and the overweight percentage (equal to: 3.03188430822361)

Equation 11-25: Common Odds Ratio Change for Type II Diabetes.

$$\text{HISD}_{worc} = \left(\frac{HIS_{D_{wor}}}{D_{wor}}\right)$$

where:

$HISD_{worc}$ = **diabetes_weighted_odds_ratio_change:** Relative change in the common odds ratio across all three weight status categories that a given member of the population within the analysis geography will be diagnosed with Type II Diabetes, based on the scenario

$HISD_{wor}$ = **scenario_diabetes_population_weighted_odds_ratio:** Common odds ratio across all three weight status categories that a given member of the population within the analysis geography will be diagnosed with Type II Diabetes, based on the scenario

D_{wor} = **diabetes_population_weighted_odds_ratio:** The common odds ratio across all three weight status categories that a given member of the population will be diagnosed with Type II Diabetes, for the baseline population (equal to: 3.60750235968925)

Equation 11-26: Incidences of Type II Diabetes

$$\text{HISD}_i = (D_{ir} * HISD_{worc})$$

where:

$HISDi$ = **diabetes_incidence:** Incidences of Type II Diabetes, based on the scenario

D_{ir} = **diabetes_incidence_rate:** The estimated baseline California statewide average incidence rate of Type II Diabetes (equal to: 0.0084)

$HISD_{worc}$ = **diabetes_weighted_odds_ratio_change:** Change in the common odds ratio across all three weight status categories that a given member of the population within the analysis geography will be diagnosed with Type II Diabetes, based on the scenario

Hypertension

The following models are designed to predict the common odds ratio of a given member of the population being diagnosed with hypertension, the change in the common odds ratio, and the overall incidences of hypertension.

Equation 11-27: Population Common Odds Ratio for Hypertension

$$\mathrm{HISH}_{wor} = ((OB_{pct} * HI_{HOBG_{wor}}) + ((OpO_{pct} - OB_{pct}) * HI_{HOWG_{wor}}) + (1 - OpO_{pct}))$$

where:

$HISH_{wor}$ = **scenario_hypertension_population_weighted_odds_ratio:** Common odds ratio that a given member of the population within the analysis geography will be diagnosed with hypertension, based on the scenario

OB_{pct} = **obesity_pct:** The percent of the population that is obese, based on the results of the results of the adult obesity percent model

HI_HOBG_{wor} = **hypertension_obese_gender_weighted_odds_ratio:** The common odds ratio for hypertension based on gender and obesity (equal to: 2.11943094629156)

OpO_{pct} = **overweight_plus_obesity_pct:** The percent of the population that is overweight + obese, based on the results of the results of the adult overweight/obesity percent model

HI_HOWG_{wor}= **hypertension_overweight_gender_weighted_odds_ratio:** The common odds ratio for hypertension based on gender and the overweight percentage (equal to: 1.43381394344917)

Equation 11-28: Common Odds Ratio Change for Hypertension

$$\mathrm{HISH}_{worc} = \left(\frac{HIS_{H_{wor}}}{H_{wor}}\right)$$

where:

$HISH_{worc}$ = **hypertension_weighted_odds_ratio_change:** Change in the common odds ratio that a given member of the population within the analysis geography will be diagnosed with hypertension, based on the scenario

$HISH_{wor}$ = **scenario_hypertension_population_weighted_odds_ratio:** Common odds ratio that a given member of the population within the analysis geography will be diagnosed with hypertension, based on the scenario

H_{wor} = **hypertension_population_weighted_odds_ratio:** The common odds ratio that a given member of the population will be diagnosed with hypertension, in general (equal to: 1.40016263704349)

Equation 11-29: Incidences of Hypertension

$$\mathrm{HISH}_{i} = (H_{ir} * HISH_{worc})$$

where:

$HISHi$ = **hypertension_incidence:** Incidences of hypertension, based on the scenario

H_{ir} = **hypertension_incidence_rate:** The average incidence rate of hypertension, in general (equal to: 0.0223148137168324)

$HISH_{worc}$ = **hypertension_weighted_odds_ratio_change:** Change in the common odds ratio that a given member of the population within the analysis geography will be diagnosed with hypertension, based on the scenario

Coronary artery disease

The following models are designed to predict the common odds ratio of a given member of the population being diagnosed with coronary artery disease, the change in the common odds ratio, and the overall incidences of coronary artery disease.

Equation 11-30: Population Common Odds Ratio for Coronary Artery Disease

$$\mathrm{HISCAD}_{wor} = ((OB_{pct} * HI_{CADOBG_{wor}}) + \left((OpO_{pct} - OB_{pct}) * HI_{CADOWG_{wor}}\right) + (1 - OpO_{pct}))$$

where:

$HISCAD_{wor}$ = **scenario_coronary_population_weighted_odds_ratio:** Common odds ratio that a given member of the population within the analysis geography will be diagnosed with coronary artery disease, based on the scenario

OB_{pct} = **obesity_pct:** The percent of the population that is obese, based on the results of the results of the adult obesity percent model

HI_CADOBG_{wor} = **coronary_obese_gender_weighted_odds_ratio:** The common odds ratio for coronary artery disease based on gender and obesity (equal to: 2.38485294117647)

OpO_{pct} = **overweight_plus_obesity_pct:** The percent of the population that is overweight + obese, based on the results of the results of the adult overweight/obesity percent model

HI_CADOWG_{wor} = **coronary_overweight_gender_weighted_odds_ratio:** The common odds ratio for coronary artery disease based on gender and the overweight percentage (equal to: 1.50201381394345)

Equation 11-31: Common Odds Ratio Change for coronary artery disease

$$\mathrm{HISCAD}_{worc} = \left(\frac{HIS_{CAD_{wor}}}{CAD_{wor}}\right)$$

where:

$HISCAD_{worc}$ = **coronary_weighted_odds_ratio_change:** Change in the common odds ratio that a given member of the population within the analysis geography will be diagnosed with coronary artery disease, based on the scenario

$HISCAD_{wor}$ = **scenario_coronary_population_weighted_odds_ratio:** Common odds ratio that a given member of the population within the analysis geography will be diagnosed with coronary artery disease, based on the scenario

CAD_{wor} = **coronary_population_weighted_odds_ratio:** The common odds ratio that a given member of the population will be diagnosed with coronary artery disease, in general (equal to: 1.48338415740942)

Equation 11-32: Incidences of coronary artery disease

$$\mathrm{HISCAD}_i = (CAD_{ir} * HISCAD_{worc})$$

where:

$HISCADi$ = **coronary_incidence:** Incidences of coronary artery disease, based on the scenario

CAD_{ir} = **coronary_incidence_rate:** The average incidence rate of coronary artery disease, in general (equal to: 0.00820208823938324)

$HISCAD_{worc}$ = **coronary_weighted_odds_ratio_change:** Change in the common odds ratio that a given member of the population within the analysis geography will be diagnosed with coronary artery disease, based on the scenario

Osteoarthritis

The following models are designed to predict the common odds ratio of a given member of the population being diagnosed with osteoarthritis, the change in the common odds ratio, and the overall incidences of osteoarthritis.

Equation 11-33: Population Common Odds Ratio for Osteoarthritis

$$\mathrm{HISO}_{wor} = ((OB_{pct} * HI_{OOBG_{wor}}) + \left((OpO_{pct} - OB_{pct}) * HI_{OOWG_{wor}}\right) + (1 - OpO_{pct}))$$

where:

$HISO_{wor}$ = **scenario_osteoarthritis_population_weighted_odds_ratio:** Common odds ratio that a given member of the population within the analysis geography will be diagnosed with osteoarthritis, based on the scenario

OB_{pct} = **obesity_pct:** The percent of the population that is obese, based on the results of the results of the adult obesity percent model

HI_OOBG_{wor} = **osteoarthritis_obese_gender_weighted_odds_ratio:** The common odds ratio for osteoarthritis based on gender and obesity (equal to: 3.12081841432225)

OpO_{pct} = **overweight_plus_obesity_pct:** The percent of the population that is overweight + obese, based on the results of the results of the adult overweight/obesity percent model

HI_OOWG_{wor}= **osteoarthritis_overweight_gender_weighted_odds_ratio:** The common odds ratio for osteoarthritis based on gender and the overweight percentage (equal to: 2.36091517375351)

Equation 11-34: Common Odds Ratio Change for Osteoarthritis.

$$\mathrm{HISO}_{worc} = \left(\frac{HIS_{O_{wor}}}{O_{wor}}\right)$$

where:

$HISO_{worc}$ = **osteoarthritis_weighted_odds_ratio_change:** Change in the common odds ratio that a given member of the population within the analysis geography will be diagnosed with osteoarthritis, based on the scenario

$HISO_{wor}$ = **scenario_osteoarthritis_population_weighted_odds_ratio:** Common odds ratio that a given member of the population within the analysis geography will be diagnosed with osteoarthritis, based on the scenario

O_{wor} = **osteoarthritis_population_weighted_odds_ratio:** The common odds ratio that a given member of the population will be diagnosed with osteoarthritis, in general (equal to: 1.93944964786176)

Equation 11-35: Incidences of Osteoarthritis

$$\mathrm{HISO}_i = (O_{ir} * HISO_{worc})$$

where:

$HISOi$ = **osteoarthritis_incidence:** Incidences of osteoarthritis, based on the scenario

O_{ir} = **osteoarthritis_incidence_rate:** The average incidence rate of osteoarthritis, in general (equal to: 0.00328)

$HISO_{worc}$ = **osteoarthritis_weighted_odds_ratio_change:** Change in the common odds ratio that a given member of the population within the analysis geography will be diagnosed with osteoarthritis, based on the scenario

Chronic back pain

The following models are designed to predict the common odds ratio of a given member of the population being diagnosed with chronic back pain, the change in the common odds ratio, and the overall incidences of osteoarthritis.

Equation 11-36: Population Common Odds Ratio for Chronic Back Pain

$$\mathrm{HISCBP}_{wor} = ((OB_{pct} * HI_{CBPOBG_{wor}}) + \left((OpO_{pct} - OB_{pct}) * HI_{CBPOWG_{wor}}\right) + (1 - OpO_{pct}))$$

where:

$HISCBP_{wor}$ = **scenario_backpain_population_weighted_odds_ratio:** Common odds ratio that a given member of the population within the analysis geography will be diagnosed with chronic back pain, based on the scenario

OB_{pct} = **obesity_pct:** The percent of the population that is obese, based on the results of the results of the adult obesity percent model

HI_CBPOBG_{wor} = **backpain_obese_gender_weighted_odds_ratio:** The common odds ratio for chronic back pain based on gender and obesity (equal to: 2.81)

OpO_{pct} = **overweight_plus_obesity_pct:** The percent of the population that is overweight + obese, based on the results of the results of the adult overweight/obesity percent model

HI_CBPOWG_{wor} = **backpain_overweight_gender_weighted_odds_ratio:** The common odds ratio for chronic back pain based on gender and the overweight percentage (equal to: 1.59)

Equation 11-37: Common Odds Ratio Change for Chronic Back Pain

$$\mathrm{HISCBP}_{worc} = (\frac{HIS_{CBP_{wor}}}{CBP_{wor}})$$

where:

$HISCBP_{worc}$ = **backpain_weighted_odds_ratio_change:** Change in the common odds ratio that a given member of the population within the analysis geography will be diagnosed with chronic back pain, based on the scenario

$HISCBP_{wor}$ = **scenario_backpain_population_weighted_odds_ratio:** Common odds ratio that a given member of the population within the analysis geography will be diagnosed with chronic back pain, based on the scenario

CBP_{wor} = **backpain_population_weighted_odds_ratio:** The common odds ratio that a given member of the population will be diagnosed with chronic back pain, in general (equal to: 1.60953677484934)

Equation 11-38: Incidences of Chronic Back Pain

$$\mathrm{HISCBP}_i = (CBP_{ir} * HISCBP_{worc})$$

where:

$HISCBPi$ = **backpain_incidence:** Incidences of chronic back pain, based on the scenario

CBP_{ir} = **backpain_incidence_rate:** The average incidence rate of chronic back pain, in general (equal to: 0.00293491396673764)

$HISCBP_{worc}$ = **backpain_weighted_odds_ratio_change:** Change in the common odds ratio that a given member of the population within the analysis geography will be diagnosed with chronic back pain, based on the scenario

Colorectal cancer

The following models are designed to predict the common odds ratio of a given member of the population being diagnosed with colorectal cancer, the change in the common odds ratio, and the overall incidences of colorectal cancer.

Equation 11-39: Population Common Odds Ratio for Colorectal Cancer

$$\mathrm{HISCC}_{wor} = ((OB_{pct} * HI_{CCOBG_{wor}}) + \left((OpO_{pct} - OB_{pct}) * HI_{CCOWG_{wor}}\right) + (1 - OpO_{pct}))$$

where:

$HISCC_{wor}$ = **scenario_colrec_cancer_population_weighted_odds_ratio:** Common odds ratio that a given member of the population within the analysis geography will be diagnosed with colorectal cancer, based on the scenario

OB_{pct} = **obesity_pct:** The percent of the population that is obese, based on the results of the results of the adult obesity percent model

HI_CCOBG_{wor} = **colrec_cancer_obese_gender_weighted_odds_ratio:** The common odds ratio for colorectal cancer based on gender and obesity (equal to: 1.81028452685422)

OpO_{pct} = **overweight_plus_obesity_pct:** The percent of the population that is overweight + obese, based on the results of the results of the adult overweight/obesity percent model

HI_CCOWG_{wor} = **colrec_cancer_overweight_gender_weighted_odds_ratio:** The common odds ratio for colorectal cancer based on gender and the overweight percentage (equal to: 1.48505719835959)

Equation 11-40: Common Odds Ratio Change for Colorectal Cancer

$$\text{HISCC}_{worc} = (\frac{HIS_{CC\,wor}}{CC_{wor}})$$

where:

$HISCC_{worc}$ = **colrec_cancer_weighted_odds_ratio_change:** Change in the common odds ratio that a given member of the population within the analysis geography will be diagnosed with colorectal cancer, based on the scenario

$HISCC_{wor}$ = **scenario_colrec_cancer_population_weighted_odds_ratio:** Common odds ratio that a given member of the population within the analysis geography will be diagnosed with colorectal cancer, based on the scenario

CC_{wor} = **colrec_cancer_population_weighted_odds_ratio:** The common odds ratio that a given member of the population will be diagnosed with colorectal cancer, in general (equal to: 1.34718942859217)

Equation 11-41: Incidences of Colorectal Cancer

$$\text{HISCC}_i = (CC_{ir} * HISCC_{worc})$$

where:

$HISCCi$ = **colrec_cancer_incidence:** Incidences of colorectal cancer, based on the scenario

CC_{ir} = **colrec_cancer_incidence_rate:** The average incidence rate of colorectal cancer, in general (equal to: 0.000472)

$HISCC_{worc}$ = **colrec_cancer_weighted_odds_ratio_change:** Change in the common odds ratio that a given member of the population within the analysis geography will be diagnosed with colorectal cancer, based on the scenario

Kidney cancer

The following models are designed to predict the common odds ratio of a given member of the population being diagnosed with kidney cancer, the change in the common odds ratio, and the overall incidences of kidney cancer.

Equation 11-42: Population Common Odds Ratio for Kidney Cancer

$$\text{HISKC}_{wor} = ((OB_{pct} * HI_{KCOBG_{wor}}) + \left((OpO_{pct} - OB_{pct}) * HI_{KCOWG_{wor}}\right) + (1 - OpO_{pct}))$$

where:

$HISKC_{wor}$ = **scenario_kidney_cancer_population_weighted_odds_ratio:** Common odds ratio that a given member of the population within the analysis geography will be diagnosed with kidney cancer, based on the scenario

OB_{pct} = **obesity_pct:** The percent of the population that is obese, based on the results of the results of the adult obesity percent model

HI_KCOBG_{wor} = **kidney_cancer_obese_gender_weighted_odds_ratio:** The common odds ratio for kidney cancer based on gender and obesity (equal to: 2.21505754475703)

OpO_{pct} = **overweight_plus_obesity_pct:** The percent of the population that is overweight + obese, based on the results of the results of the adult overweight/obesity percent model

HI_KCOWG_{wor} = **kidney_cancer_overweight_gender_weighted_odds_ratio:** The common odds ratio for kidney cancer based on gender and the overweight percentage (equal to: 1.574599611)

Equation 11-43: Common Odds Ratio Change for Kidney Cancer

$$\mathrm{HISKC}_{worc} = (\frac{HIS_{KC_{wor}}}{KC_{wor}})$$

where:

$HISKC_{worc}$ = **kidney_cancer_weighted_odds_ratio_change:** Change in the common odds ratio that a given member of the population within the analysis geography will be diagnosed with kidney cancer, based on the scenario

$HISKC_{wor}$ = **scenario_kidney_cancer_population_weighted_odds_ratio:** Common odds ratio that a given member of the population within the analysis geography will be diagnosed with kidney cancer, based on the scenario

KC_{wor} = **kidney_cancer_population_weighted_odds_ratio:** The common odds ratio that a given member of the population will be diagnosed with kidney cancer, in general (equal to: 1.47)

Equation 11-44: Incidences of Kidney Cancer

$$\mathrm{HISKC}_{i} = (KC_{ir} * HISKC_{worc})$$

where:

$HISKCi$ = **kidney_cancer_incidence:** Incidences of kidney cancer, based on the scenario

KC_{ir} = **kidney_cancer_incidence_rate:** The average incidence rate of kidney cancer, in general (equal to: 0.000146)

$HISKC_{worc}$ = **kidney_cancer_weighted_odds_ratio_change:** Change in the common odds ratio that a given member of the population within the analysis geography will be diagnosed with kidney cancer, based on the scenario

Fiscal Impacts of Weight And Activity-Related Health Outcomes

Being overweight or obese is associated with significantly higher health care expenditures, in addition to reductions in productivity and quality of life. Relationships derived from published studies were used to calculate three classes of per capita fiscal impacts of estimated weight and activity-based health conditions.[68,69,70,71,72] All costs were adjusted from the original data date to a May 2011 equivalent by using the Consumer Price Index, and include:

- Medical costs: direct capital expenses related to a medical condition, such as doctor and hospital visits, prescription medicine, emergency services, etc.
- Productivity costs: indirect costs related to lost or reduced work productivity as a result of a medical condition.
- Quality-adjusted life years (QALYs) lost: an estimate of the economic value of a reduction in quality-of-life years lost as a result of a medical condition.

Fiscal impacts of being obese

The following models are designed to predict the fiscal impacts of obesity.

Equation 11-45: Medical Costs of Obesity

$$\mathrm{OB}_{mc} = \left(\left(PM_{20_{64}} + PF_{20_{64}}\right) * OB_{pct}\right) * OB_{mcr}$$

where:

OB_{mc} = **obesity_medical_cost:** Medical costs associated with obesity

PM_{20_64} = **pop_male_age20_64:** The total amount of male adult population (aged 20 to 64)

PF_{20_64} = **pop_female_age20_64:** The total amount of female adult population (aged 20 to 64)

OB_{pct} = **obesity_pct:** The percent of the population that is obese, based on the results of the adult obesity percent model

OB_{mcr} = **obesity_medical_cost_per_cap:** The medical cost per capita of obesity for each obese individual (equal to: $1,363.94983625071)

Equation 11-46: Productivity Costs of Obesity

$$\mathrm{OB}_{pc} = \left(\left(PM_{20_{64}} + PF_{20_{64}}\right) * OB_{pct}\right) * OB_{pcr}$$

where:

OB_{pc} = **obesity_productivity_cost:** Productivity-loss costs associated with obesity per person

PM_{20_64} = **pop_male_age20_64:** The total amount of male adult population (aged 20 to 64)

PF_{20_64} = **pop_female_age20_64:** The total amount of female adult population (aged 20 to 64)

OB_{pct} = **obesity_pct:** The percent of the population that is obese, based on the results of the adult obesity percent model

[68] Thorpe at al. The Impact of Obesity on Rising Medical Spending. Health Affairs. 2004.

[69] Durden et al. Economic Costs of Obesity to Self-Insured Employers. Journal of Occupational and Environmental Medicine. 2008; 50: 991:997.

[70] Groessl et al. Body Mass Index and Quality of Well-Being in a Community of Older Adults. American Journal of Preventive Medicine. 2004; 26: 126-129.

[71] Cutler & Richardson. Measuring the Health of the US population.

[72] Viscusi & Aldy. The value of a statistical life: a critical review of market estimates throughout the world.

OB_{pcr} = **obesity_productivity_cost_per_cap:** The productivity-loss cost per capita of obesity for each obese individual (equal to: $1,748.2416999488)

Equation 11-47: Costs of Loss of QALYs of Obesity

$$\mathrm{OB}_{qc} = \left(\left(PM_{20_{64}} + PF_{20_{64}}\right) * OB_{pct}\right) * OB_{qcr}$$

where:

OB_{qc} = **obesity_qaly_cost:** Costs associated with the loss of QUALYs due to obesity

PM_{20_64} = **pop_male_age20_64:** The total amount of male adult population (aged 20 to 64)

PF_{20_64} = **pop_female_age20_64:** The total amount of female adult population (aged 20 to 64)

OB_{pct} = **obesity_pct:** The percent of the population that is obese, based on the results of the adult obesity percent model

OB_{qcr} = **obesity_qaly_cost_per_cap:** The cost associated with the loss of QUALYs due to obesity for each obese individual (equal to: $2,005.2558574722)

Equation 11-48: Total Costs of Obesity

$$\mathrm{OB}_{c} = \mathrm{OB}_{mc} + \mathrm{OB}_{pc} + \mathrm{OB}_{qc}$$

where:

OB_{c} = **obesity_total_cost:** Total costs due to obesity

OB_{mc} = **obesity_medical_cost:** Medical costs associated with obesity

OB_{pc} = **obesity_productivity_cost:** Productivity-loss costs associated with obesity

OB_{qc} = **obesity_qaly_cost:** Costs associated with the loss of QUALYs due to obesity

Fiscal impacts of being overweight

The following models are designed to predict the fiscal impacts of being overweight.

Equation 11-49: Medical Costs of Overweight

$$\mathrm{OW}_{mc} = \left(\left(PM_{20_{64}} + PF_{20_{64}}\right) * \left(OpO_{pct} - OB_{pct}\right)\right) * OW_{mcr}$$

where:

OB_{mc} = **obesity_medical_cost:** Medical costs associated with overweight

PM_{20_64} = **pop_male_age20_64:** The total amount of male adult population (aged 20 to 64)

PF_{20_64} = **pop_female_age20_64:** The total amount of female adult population (aged 20 to 64)

OpO_{pct} = **overweight_plus_obesity_pct:** The percent of the population that is overweight + obese, based on the results of the results of the adult overweight/obesity percent model

OB_{pct} = **obesity_pct:** The percent of the population that is obese, based on the results of the adult obesity percent model

OW_{mcr} = **overweight_medical_cost_per_cap:** The medical cost per capita of overweight for each overweight individual (equal to: $433.810050818746)

Equation 11-50: Productivity Costs of Overweight

$$\text{OW}_{pc} = \left(\left(PM_{20_{64}} + PF_{20_{64}}\right) * \left(OpO_{pct} - OB_{pct}\right)\right) * OW_{pcr}$$

where:

OW_{pc} = **overweight_productivity_cost:** Productivity-loss costs associated with overweight

PM_{20_64} = **pop_male_age20_64:** The total amount of male adult population (aged 20 to 64)

PF_{20_64} = **pop_female_age20_64:** The total amount of female adult population (aged 20 to 64)

OpO_{pct} = **overweight_plus_obesity_pct:** The percent of the population that is overweight + obese, based on the results of the results of the adult overweight/obesity percent model

OB_{pct} = **obesity_pct:** The percent of the population that is obese, based on the results of the adult obesity percent model

OW_{pcr} = **overweight_productivity_cost_per_cap:** The productivity-loss cost per capita of overweight for each overweight individual (equal to: $1,624.44165898618)

Equation 11-51: Costs of Loss of QALYs of Overweight

$$\text{OW}_{qc} = \left(\left(PM_{20_{64}} + PF_{20_{64}}\right) * \left(OpO_{pct} - OB_{pct}\right)\right) * OW_{qcr}$$

where:

OW_{qc} = **overweight_qaly_cost:** Costs associated with the loss of QUALYs due to overweight

PM_{20_64} = **pop_male_age20_64:** The total amount of male adult population (aged 20 to 64)

PF_{20_64} = **pop_female_age20_64:** The total amount of female adult population (aged 20 to 64)

OpO_{pct} = **overweight_plus_obesity_pct:** The percent of the population that is overweight + obese, based on the results of the results of the adult overweight/obesity percent model

OB_{pct} = **obesity_pct:** The percent of the population that is obese, based on the results of the adult obesity percent model

OW_{qcr} = **overweight_qaly_cost_per_cap:** The cost associated with the loss of QUALYs due to overweight for each overweight individual (equal to: $610.295260969799)

Equation 11-52: Total Costs of Overweight

$$\text{OW}_c = \text{OW}_{mc} + \text{OW}_{pc} + \text{OW}_{qc}$$

where:

OW_c = **overweight_total_cost:** Total costs due to overweight

OW_{mc} = **overweight_medical_cost:** Medical costs associated with overweight

OW_{pc} = **overweight_productivity_cost:** Productivity-loss costs associated with overweight

OW_{qc} = **overweight_qaly_cost:** Costs associated with the loss of QUALYs due to overweight

Pollution-Related Health Impacts

UrbanFootprint calculates the public health impacts of transportation-related air pollution. The number of avoided health incidences and related costs are calculated on the basis of criteria air pollutant emissions (measured in tons), which are determined by VMT and per-mile emissions rate assumptions.[73] These metrics express differences among scenarios, rather than measurements of total health incidences or costs.

Version 1.0 of the model includes system-wide respiratory impacts. That is, it examines the respiratory impacts and costs associated with changes in overall VMT and pollutant emissions. Model advancements will allow for additional measurements of geographically specific emissions and their associated health impacts.

Pollution-Related Health Incidence Assumptions

The health incidence assumptions quantify the avoided incidences per ton of emissions of various pollutants, including PM2.5, SOx, NOx, and VOC. The assumptions, shown in Table 3, are based on national data from the EPA, Office of Air Quality Planning & Standards, Air Benefit and Cost Group,[74] and were estimated to 2035 by TIAX, LLC for the American Lung Association.

Respiratory health incidences include cases of: premature mortality; chronic bronchitis; acute myocardial infarction; respiratory and cardiovascular hospitalizations; respiratory-related ER visits; acute bronchitis; work loss days; asthma exacerbation; and acute, lower, and upper respiratory symptoms. Per-ton assumptions for each of these incidences are individually applied to scenario-total emissions of the following criteria pollutants: $PM_{2.5}$, SO_x, NO_x, and VOC.

Table 11-5: Health Incidences per Ton of Pollutant Emissions (year 2035)

	PM2.5	SO_x	VOC	NO_x
Premature Mortality (Pope 2002)	0.07631	0.00078	0.00594	0.00619
Chronic Bronchitis	0.03417	0.00035	0.00264	0.00276
Acute Myocardial Infarction	0.07272	0.00076	0.00565	0.00609
Hospitalization: Respiratory	0.00882	0.00009	0.00069	0.00072
Hospitalization: Cardiovascular	0.01982	0.00021	0.00154	0.00165
ER visits (respiratory related)	0.01754	0.00018	0.00135	0.00142
Acute Bronchitis	0.08750	0.00089	0.00671	0.00709
Work Loss Days	6.48295	0.06564	0.50044	0.51187
Asthma Exacerbation	0.95418	0.00969	0.07339	0.07681
Acute Respiratory Symptoms	38.23382	0.38744	2.95034	3.02214

[73] California pollutant emissions rate assumptions from CARB Emissions Factors Model (EMFAC 2011).

[74] Cases-per-ton estimates from Neal Fann of US Environmental Protection Agency (EPA). Premature mortality is the average of the American Cancer Society study (Pope et al. 2002) and the Six-Cities study (Laden et al., 2006). The rounded Six-Cities benefits per ton results are presented in the EPA's Environmental Benefits Mapping and Analysis Program website: www.epa.gov/oaqps001/benmap/bpt.html. As presented by Chan, M. and Jackson, MD (TIAX LLC) for the American Lung Association in California. *Health Impact of Land Use VMT and In-Use Vehicle Fleets*. 2011.

Lower Respiratory Symptoms	1.04022	0.01060	0.07988	0.08416
Upper Respiratory Symptoms	0.78766	0.00801	0.06068	0.06357

Pollution-Related Health Incidence Calculations

Avoided health incidences are calculated, by type, on the basis of assumptions of the number of incidences that occur per ton of pollutant emissions. The first step is to calculate, for each scenario, the number of health incidences of a certain type. This is done by applying per-ton assumptions to emissions of the following criteria pollutants: PM2.5, SO_x, NO_x, and VOC, then adding together the results.

Equation 11-53: Health Incidences by Type, by Scenario

$$HI_{tSx} = \sum_{for\ all\ p} (I_{tp} * E_p)$$

where:

HI_t = Annual health incidences of type t in Scenario x

I_{tp} = Assumed health incidences of type t per ton of pollutant p

E_p = Emissions of pollutant p (tons)

The interim results can then be used to calculate the final metric – avoided health incidences, which are measured as the difference between scenarios.

Equation 11-54: Avoided Health Incidences by Type

$$AHI_{tS2} = \mathrm{HI}_{\mathrm{tS1}} - HI_{tS2}$$

where:

AHI_{tS2} = Avoided health incidences of type t for Scenario 2 as compared to Scenario 1

HI_{tS1} = Health incidences of type t in Scenario 1

HI_{tS2} = Health incidences of type t in Scenario 2

The health incidences of different types are then added together for a grand total.

Equation 11-55: Total Avoided Health Incidences

$$\mathrm{T_{Sx}} = \sum_{for\ all\ t} AHI_{tSx}$$

where:

T_{Sx} = Total annual avoided health incidences for Scenario x

AHI_{tSx} = Avoided health incidences of type t for Scenario x as compared to any other scenario

Pollution-Related Health Cost Assumptions

Respiratory health costs are based on per-ton valuations of emissions of the following pollutants: $PM_{2.5}$, SO_x, NO_x, CO, VOC, and indirect PM from NO_x, SO_x, and VOC. These valuations, shown in Table 4, are based on analyses by California state and federal agencies, and were estimated to 2035 by TIAX, LLC for the American Lung Association.[75]

As for health incidences, these valuations are applied to emissions of individual pollutants, and then totaled. Due to the complexity of measuring pollution-related health incidences and costs in an integrated manner, the cost assumptions and results are generally, rather than directly, related to the numbers of health incidences as calculated by the model.

Table 11-6: Pollutant Valuations per Ton (year 2035 valuations, represented in 2009 dollars)

	Pollutant Valuations (2010$/ton)
Direct PM2.5	$756,413
Indirect PM: NO_x	$58,841
Indirect PM: SO_x	$61,386
Indirect PM: VOC	$7,778
Ozone (NO_x+VOC): Health[76]	$1,648

Pollution-Related Health Cost Calculations

Avoided health costs are calculated, by pollutant, on the basis of assumptions of cost per ton of pollutant emissions. The first step is to calculate the health costs for each scenario. This is done by applying per-ton assumptions to emissions of the following criteria pollutants: SO_x, NO_x, CO, VOC, and indirect PM from NO_x, SO_x, and VOC, then adding together the results.

Equation 11-56: Health Costs by Pollutant, by Scenario.

$$HC_{Sx} = \sum_{for\ all\ p} (C_p * E_p)$$

where:

HC_{Sx} = Annual health costs in Scenario x

C_p = Assumed health costs per ton of pollutant p

E_p = Emissions of pollutant p (tons)

The interim results can then be used to calculate the final metric – avoided health costs, which are measured as the difference between scenarios.

[75] PM-related valuations (Neal Fann of EPA) used average of American Cancer Society (ACS) study (Pope et al. 2002) and Six-Cities study (Laden et al., 2006). The Six-Cities study is about 145% larger than the ACS study. Ozone and visibility valuations calculated based upon national results presented in the latest EPA report "The Benefits and Costs of the Clean Air Act from 1990 to 2020" (March 2011).

[76] Ozone emissions are approximated by summing the ozone precursors NOx and VOC. Valuations based upon the discount rate of 3%.

Equation 11-57: Avoided Health Costs by Type

$$AHC_{S2} = \mathrm{C}_{\mathrm{S1}} - C_{S2}$$

where:

AHC_{S2} = Avoided health costs for Scenario 2 as compared to Scenario 1

C_{tS1} = Health costs in Scenario 1

C_{tS2} = Health costs in Scenario 2

The health costs of different types are then added together for a grand total.

Equation 11-58: Total Avoided Health Incidences

$$\mathrm{T}_{\mathrm{Sx}} = \sum_{for\ all\ t} AHC_{Sx}$$

where:

T_{Sx} = Total annual avoided health costs for Scenario x

A_{tSx} = Avoided health costs for Scenario x as compared to any other scenario

Pedestrian Safety

UrbanFootprint's estimates of pedestrian-vehicle collisions are informed by data that associates per capita vehicle miles traveled (VMT) and pedestrian-auto collisions.[77] These data demonstrate a strong relationship between changes in per-capita VMT and changes in per-capita collisions. As VMT rises, so does the collision rate; as VMT falls, pedestrian-car collisions also fall.

UrbanFootprint's public health engine produces future scenario-wide estimates of pedestrian-auto collisions based on a predicted collision rate. A per-capita collision rate is calculated by multiplying change in daily per-capita VMT over time, as estimated by the UrbanFootprint travel engine, by the 2009 per-capita California pedestrian-vehicle collision rate, as documented by California Highway Patrol data.[78] A scenario's total collision incidence is calculated by multiplying this rate by future population. UrbanFootprint does not estimate the incidence of vehicle-pedestrian collisions at the local level.

As with weight and activity-related conditions, cost factors for medical costs, productivity costs, and quality-adjusted life years (QALYs) lost are applied to pedestrian-vehicle collisions to produce estimates of their fiscal impacts.[79]

[77] Ferreira J, Minikel E. *Pay-as-you-drive Auto Insurance in Massachusetts: A Risk Assessment and Report on Consumer, Industry, and Environmental Benefits, Conservation Law Foundation Report*. November 2010.
[78] California Highway Patrol. *2009 Annual Report of Fatal and Injury Motor Vehicle Traffic Collisions*. Available: www.chp.ca.gov/switrs/switrs2009.html (accessed July 11, 2011).
[79] FHWA. Crash Cost Estimates by Maximum Police-Reported Injury Severity Within Selected Crash Geometries. October 2005. http://www.cmfclearinghouse.org/collateral/Crash_Cost_Estimates.pdf

Pre-process steps to calculate pedestrian/motor vehicle collisions

Total impacts of vehicle-pedestrian collisions are measured first for the base year in order to calibrate the model. Total regional annual VMT per capita is calculated, as well as total collisions, and the base year total costs due to medical expenses, emergency service costs, property damage costs and productivity losses, as well as the costs of QALYs lost for the base year; this is added up to produce the total base year costs for vehicle-pedestrian collisions.

Equation 11-59: Calculate annual VMT per capita in the base year

$$\mathrm{SVMTcap}_{byr} = ((\sum(VMTcap_{byr} * POP_{byr}))/\sum(POP_{byr}))$$

where:

$SVMTcap_{byr}$ = **vmt_annual_per_capita_baseyear:** Total regional annual VMT per capita for the base year

$VMTcap_{byr}$ = **b.vmt_annual_per_capita:** Annual VMT per capita for each analysis unit (grid cell, at UrbanFootprint v1.0)

POP_{byr} = **b.pop:** Total population within each analysis unit (grid cell, at UrbanFootprint v1.0)

Equation 11-60: Calculate collisions in the base year

$$\mathrm{VPC}_{byr} = VPC_r * (\sum POP_{byr})$$

where:

VPC_{byr} = **collisions_baseyear:** Total vehicle-pedestrian collisions for the base year

VPC_r = **collision_rate:** The vehicle-pedestrian collision rate (from SWITRS data; equal to: 0.000330837347851058)

POP_{byr} = **b.pop:** Total population within each analysis unit (grid cell, at UrbanFootprint v1.0)

Equation 11-61: Calculate the sum of medical + emergency service + property damage + productivity loss costs for the base year

$$\mathrm{VPC}_{mpcbyr} = VPC_{byr} * VPC_{mpcr}$$

where:

VPC_{mpcbyr} = **collisions_medprod_cost_baseyear:** Sum of the medical expenses, emergency service costs, property damage costs and productivity loss costs related to vehicle-pedestrian collisions in the base year

VPC_{byr} = **collisions_baseyear:** Total vehicle-pedestrian collisions for the base year

VPC_{mpcr} = **collisions_medprod_cost_per_cap:** The medical expenses, emergency service costs, property damage costs and productivity loss cost rate per collision related to vehicle-pedestrian collisions (equal to: $120,780.055091979)

Equation 11-62: Calculate the vehicle-pedestrian collisions total cost of QALYs lost for the base year

$$\mathrm{VPC}_{qalybyr} = \mathrm{VPC}_{byr} * VPC_{qalycap}$$

where:

$VPC_{qalybyr}$ = **collisions_qaly_cost_baseyear:** The total QALY related to vehicle-pedestrian collisions in the base year

VPC_{byr} = **collisions_baseyear:** Total vehicle-pedestrian collisions for the base year

$VPC_{qalycap}$ = **collisions_qaly_cost_per_cap:** The QALY cost per collision related to vehicle-pedestrian collisions (equal to: $184,781.471341274)

Equation 11-63: Calculate the vehicle-pedestrian collisions total costs for the base year

$$\mathrm{VPC}_{cbyr} = (VPC_{mpcbyr} + VPC_{qalybyr})$$

where:

VPC_{cbyr} = **collisions_total_cost_baseyear:** The total costs related to vehicle-pedestrian collisions in the base year

VPC_{mpcbyr} = **collisions_medprod_cost_baseyear:** Sum of the medical expenses, emergency service costs, property damage costs and productivity loss costs related to vehicle-pedestrian collisions in the base year

$VPC_{qalybyr}$ = **collisions_qaly_cost_baseyear:** The total QALY related to vehicle-pedestrian collisions in the base year

Fiscal impacts of pedestrian/motor vehicle collisions for future scenarios

Total fiscal impacts of vehicle-pedestrian collisions for a future scenario are measured using roughly the same methodology as for the base, except for total collisions. Total regional annual VMT per capita is calculated for the future scenario. Total collisions are calculated based on the change in VMT between the base year and the future scenario. The total costs are based on the sum of medical expenses, emergency service costs, property damage costs and productivity loss costs, as well as the costs of QALYs lost.

Equation 11-64: Calculate annual VMT per capita for the future scenario

$$\mathrm{SVMTcap}_{sfyr} = ((\sum (VMTcap_{sfyr} * POP_{sfyr}))/\sum (POP_{sfyr}))$$

where:

$SVMTcap_{sfyr}$ = **vmt_annual_per_capita_scenario_futureyear:** Total regional annual VMT per capita for the scenario in a future year

$VMTcap_{sfyr}$ = **f.vmt_annual_per_capita:** Annual VMT per capita for each analysis unit (grid cell, at UrbanFootprint v1.0) for the scenario in a future year

POP_{sfyr} = **f.pop:** Total population within each analysis unit (grid cell, at UrbanFootprint v1.0) for the scenario in a future year

Equation 11-65: Calculate collisions for the future scenario

$$\mathrm{VPC}_{sfyr} = VPC_r * (\sum POP_{sfyr}) * (\frac{\mathrm{SVMTcap}_{sfyr}}{\mathrm{SVMTcap}_{byr}})$$

where:

VPC_{sfyr} = **collisions_scenario_futureyear:** Total vehicle-pedestrian collisions for the scenario in a future year

VPC_r = **collision_rate:** The vehicle-pedestrian collision rate (from SWITRS data; equal to: 0.000330837347851058)

POP_{sfyr} = **f.pop:** Total population within each analysis unit (grid cell, at UrbanFootprint v1.0) for the scenario in a future year

$SVMTcap_{sfyr}$ = **vmt_annual_per_capita_scenario_futureyear:** Total regional annual VMT per capita for the scenario in a future year

$SVMTcap_{byr}$ = **vmt_annual_per_capita_baseyear:** Total regional annual VMT per capita for the base year

Equation 11-66: Calculate the sum of medical expenses, emergency service costs, property damage costs and productivity loss costs for the future scenario

$$\mathrm{VPC}_{mpcsfyr} = VPC_{sfyr} * VPC_{mpcr}$$

where:

$VPC_{mpcsfyr}$ = **collisions_medprod_cost_scenario_futureyear:** Sum of the medical expenses, emergency service costs, property damage costs and productivity loss costs related to vehicle-pedestrian collisions for the scenario in a future year

VPC_{sfyr} = **collisions_scenario_futureyear:** Total vehicle-pedestrian collisions for the scenario in a future year

VPC_{mpcr} = **collisions_medprod_cost_per_cap:** The medical expense, emergency service cost, property damage cost and productivity loss cost rate per collision related to vehicle-pedestrian collisions

Equation 11-67: Calculate the vehicle-pedestrian collisions total cost of QALYs lost for the future scenario

$$\mathrm{VPC}_{qalysfyr} = \mathrm{VPC}_{sfyr} * VPC_{qalycap}$$

where:

$VPC_{qalysfyr}$ = **collisions_qaly_cost_scenario_futureyear:** The total QALY related to vehicle-pedestrian collisions for the scenario in a future year

VPC_{sfyr} = **collisions_scenario_futureyear:** Total vehicle-pedestrian collisions for the scenario in a future year

$VPC_{qalycap}$ = **collisions_qaly_cost_per_cap:** The QALY cost per collision related to vehicle-pedestrian collisions (equal to: $184,781.471341274)

Equation 11-68: Calculate the vehicle-pedestrian collisions total costs for the future scenario

$$\mathrm{VPC}_{csfyr} = (VPC_{mpcsfyr} + VPC_{qalysfyr})$$

where:

VPC_{csfyr} = **collisions_total_cost_scenario_futureyear:** The total costs related to vehicle-pedestrian collisions for the scenario in a future year

$VPC_{mpcsfyr}$ = **collisions_medprod_cost_scenario_futureyear:** Sum of the medical expenses, emergency service costs, property damage costs and productivity loss costs related to vehicle-pedestrian collisions for the scenario in a future year

$VPC_{qalysfyr}$ = **collisions_qaly_cost_scenario_futureyear:** The total QALY related to vehicle-pedestrian collisions for the scenario in a future year

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CHAPTER 12
Fiscal Impacts

Fiscal impact analysis allows users to compare the implications of varying forms of development on local revenues and expenditures. Version 1.0 of the UrbanFootprint fiscal impact engine limits its focus to the impacts associated with new residential growth; it accounts for the capital costs of new and upgraded local infrastructure; local operations and maintenance (O&M) costs to serve new and upgraded infrastructure; and major sources of city revenues. Cost and revenue factors – which are derived from a number of local, regional, state, and utility sources – vary by: Land Development Category (LDC: Urban, Compact or Standard); development condition (refill or greenfield); and housing type (single family detached large lot, single family detached small lot, single family attached or multifamily). This section describes how the per-housing unit or per-capita factors are derived, and how fiscal impacts are subsequently quantified in UrbanFootprint v1.0.

Calthorpe Associates worked with the urban and regional economics consulting and research firm Strategic Economics to develop the assumptions that drive infrastructure cost estimates, O&M costs, and revenues. The capital and O&M cost assumptions are based on a survey of impact fees and municipal expenditures, while revenue assumptions are based on property values and household retail expenditures based on statewide and local data sources.

Note that UrbanFootprint v1.0 estimates the impacts of variations in *residential* development unit types and patterns; future versions will incorporate the fiscal impacts due to *employment* development variations. Future advancements will also include other methods for calculating local and regional fiscal impacts, including integration of the Sacramento Area Council of Government's (SACOG) IMPACS model, as well as the additional of more cost categories.

Land Development Categories

UrbanFootprint's fiscal impacts analysis module is sensitive to cost and revenue variations among three Land Development Categories, and refill or greenfield development conditions. The LDCs – Urban, Compact, and Standard – represent distinct forms of land use, ranging from dense and walkable mixed-use urban areas well served by transit, to lower-intensity, less walkable places where land uses are segregated and most trips are made via automobile. Each UrbanFootprint place type fits into a single LDC, as summarized in Table 12-1.

Table 12-1: UrbanFootprint Place Type-to-LDC Crosswalk

PTID	UrbanFootprint Place Type	Land Development
1	Urban Mixed Use	Urban
2	Urban Residential	Urban
3	Urban Commercial	Urban
4	City Mixed Use	Urban
5	City Residential	Urban
6	City Commercial	Urban

7	Town Mixed Use	Compact
8	Town Residential	Compact
9	Town Commercial	Compact
10	Village Mixed Use	Compact
11	Village Residential	Compact
12	Village Commercial	Compact
13	Neighborhood Residential	Compact
14	Neighborhood Low	Compact
15	Office Focus	Standard
16	Mixed Office and R&D	Standard
17	Office/Industrial	Standard
18	Industrial Focus	Standard
19	Low-Density Employment Park	Standard
20	High Intensity Activity Center	Compact
21	Mid Intensity Activity Center	Standard
22	Low Intensity Retail-Centered N'Hood	Standard
23	Retail: Strip Mall/ Big Box	Standard
24	Industrial/Office/Res Mixed High	Standard
25	Industrial/Office/Res Mixed Low	Standard
26	Suburban Multifamily	Standard
27	Suburban Mixed Residential	Standard
28	Residential Subdivision	Standard
29	Large Lot Residential Area	Standard
30	Rural Residential	Standard
31	Rural Ranchettes	Standard
32	Rural Employment	Standard
33	Campus/ University	Standard
34	Institutional	Standard
35	Parks & Open Space	Standard

The distinct forms of growth represented by the Land Development Categories result in differences in fiscal performance. The three Land Development Categories are described below. Note that this description of LDCs provides a general overview of the conceptual framework underlying LDC classification; while not all of the attributes described are directly relevant to the operation of the fiscal impacts module, the description helps to convey why certain place types are mapped to specific LDCs.

- **Urban**: this represents the most intense and most mixed of the Land Development Categories, which in most cases would be found within and directly adjacent to moderate and high density urban centers. Virtually all of the development that falls into the Urban LDC would be considered infill or redevelopment. The majority of housing in Urban areas tends to be multifamily and attached single family (townhome), with some small-lot single family homes.

It is assumed that Urban growth is supported by high levels of regional and local transit service (likely on dedicated rights of way and including multiple modes such as rail, bus, and ferry), and that well-connected street networks and the mix and intensity of uses result in a highly walkable environment that leads to a relatively low dependence on the automobile for many trips. The per-capita VMT of those living in Urban environments tends to be far lower than average and generally range, in California, from 1,500 to 4,500 per year. The housing types in Urban areas tend to consume less water and energy than the larger types found in greater proportion in less urban locations.

- **Compact**: this Land Development Category is less intense than the Urban category, but is nonetheless highly walkable and contains a rich mix of retail, commercial, residential, and civic uses. The Compact form is most likely to occur as new growth on the urban edge or as larger-scale (ground-up) redevelopment within urban areas. Compact areas contain a rich mix of housing, from multifamily and attached single family (townhome) to small- and medium-lot single family homes.

  It is assumed that Compact growth is well served by regional and local transit service, but may not benefit from as much service as Urban growth, and is less likely to occur around major multimodal hubs. Streets are well connected and walkable, and destinations such as schools, shopping, and entertainment areas can typically be reached via a walk, bike, transit, or short auto trip. The per-capita VMT of those living in Compact environments tends to be lower than average and generally ranges from 4,500 to 7,500 per year in California. While the mix of housing types in Compact areas is generally not as resource-efficient as that in Urban areas, they tend to consume less energy and water than the larger types found in the Standard LDC.

- **Standard**: this Land Development Category represents the majority of separate-use auto-oriented development that has dominated the American suburban landscape over the past five to six decades. Densities tend to be lower than that of the Compact LDC, and are generally not highly mixed or organized in ways that facilitate walking, biking, or transit service. While Standard can contain a wide variety of housing types, including attached and multifamily units, medium- and larger-lot single family homes tend to comprise the majority of this development form.

  The lower densities and decreased mix of uses in the Standard LDC are not typically well served by regional transit service, and most trips are made by car. The built environment tends to be oriented around automobile usage as the primary mode for mobility, with a low index of street intersections per square mile, many discontinuous streets that serve to channel traffic only onto arterials, long block faces, single-use zoning and a location around the periphery of the urban region. The per-capita VMT of those living in Standard environments tends to be higher than average due to auto dependence for most trips, and generally ranges from 7,500 to 18,000 per year in California. The larger single family housing types that dominate this development form tend to consume more energy and water than those in the Urban or Compact LDCs.

Examples (analogues) of California cities or communities that would fall into these Land Development Categories are provided in Table 12-2.

Table 12-2: Sample California places by Land Development Category.[80]

Sampled Analogue Area	Annual VMT per Capita	Difference from State Average
STANDARD LDC Average	13,746	70%
Santa Clarita	18,787	132%
Chino Hills	18,455	128%
Desert View Highlands	17,656	118%
San Clemente	17,598	117%
Thousand Oaks	16,269	101%
Simi Valley	15,802	95%
Azusa	14,396	78%
North Livermore	12,806	58%
North Lancaster	12,057	49%
Palmdale	11,902	47%
Discovery Bay	11,572	43%
San Ramon	9,985	23%
Pleasanton	9,953	23%
Vacaville	9,551	18%
Morgan Hill/San Martin	9,397	16%
COMPACT LDC Average	5,919	-27%
Emeryville	7,407	-9%
San Mateo	6,757	-17%
Franklin Park, Hollywood	6,283	-22%
Albany	6,106	-25%
Fairfax Area, Los Angeles	5,716	-29%
Hayward	4,733	-42%
URBAN LDC Average	2,630	-68%
Central Berkeley	4,208	-48%
San Francisco (Countywide)	4,133	-49%
Downtown Oakland	2,294	-72%
Mission District (SF)	2,012	-75%
Pacific Heights (SF)	1,673	-79%
North Beach (SF)	1,461	-82%

[80] Source: TAZ-level data from Holtzclaw (Holtzclaw, Clear, Dittmar, Goldstein, & Haas, 2002).

Fiscal Impact Model Assumptions

This section outlines the per-housing unit and per-capita cost and revenue factors used by UrbanFootprint. The factors, which vary by LDC, refill or greenfield development condition (for the Compact LDC), and housing unit type, were originally developed by Strategic Economics and Calthorpe Associates in 2010 to estimate the fiscal impacts of statewide scenarios for the Vision California project using the RapidFire model; fiscal assumptions research and its application within Calthorpe Associates' RapidFire model was funded by the ClimateWorks foundation and the Energy Foundation. Subsequent work was done to create a refined set of factors for the Southern California Association of Governments (SCAG) region. *Fiscal Impacts Appendix I: Study for Statewide Scenarios* on page 12-11 and *Fiscal Impacts AppendixI I: Study for Southern California* on page 12-37 detail the process and assumptions.

Infrastructure Costs

One-time capital costs for local infrastructure are estimated on the basis of per-housing unit cost factors. The assumed factors are comprised of three component costs: streets and transportation, water supply, and sewage and wastewater.[81] The component costs can be added together to produce a per-unit total infrastructure cost by housing type and land development category. Assumptions for the Compact land development category also vary by development condition since the per-unit average costs associated with refill (infill or redevelopment) and greenfield development differ. Table 12-3 shows the total capital infrastructure cost assumptions for California by residential unit type and LDC; Table 12-4 shows those values for Southern California. Costs are assumed to remain constant over time.

Table 12-3: Statewide Capital Local Infrastructure Cost Assumptions per New Housing Unit (2010 dollars.)

	Urban	Compact-Refill	Compact-Greenfield	Standard
SF Large Lot	$5,711	$5,541	$9,600	$14,102
SF Small Lot	$5,711	$4,868	$9,244	$13,356
Townhome	$5,711	$5,016	$9,127	$12,740
Multifamily	$4,587	$4,518	$7,379	$11,044

Table 12-4: Southern California Local Capital Infrastructure Cost Assumptions per New Housing Unit (2008 dollars.)

	Urban	Compact-Refill	Compact-Greenfield	Standard
SF Large Lot	$8,465	$6,836	$9,600	$14,102
SF Small Lot	$6,720	$6,402	$9,243	$13,357
Townhome	$6,720	$6,580	$9,127	$12,739
Multifamily	$5,447	$6,094	$7,378	$11,044

[81] For itemized costs by LDC and unit type, see: Table 16 through Table 19 in *Fiscal Impacts Appendix I: Study for Statewide Scenarios* and Table 61 through Table 64 in *Fiscal Impacts Appendix II: Study for Southern California*. Note that capital costs for parks were produced by the Strategic Economics studies, but were excluded at this stage due to the need for further study, analysis, and vetting.

Operations and Maintenance (O&M) Costs

Ongoing annual operations and maintenance (O&M) cost assumptions for local infrastructure focus on local spending related to engineering and public works functions.[82] These component costs produce a per-unit total O&M cost by housing unit type and land development category. Assumptions for the Compact land development category also vary by development condition since the per-unit average costs associated with refill and greenfield development differ. If desired, the component assumptions can be used to model costs for individual categories – for example, O&M costs for public works or engineering functions alone. Table 12-5 shows the total O&M cost assumptions for California (the values were found to be approximately the same statewide as in Southern California).

Table 12-5: Statewide Annual Local Operations and Maintenance Cost Assumptions (2010 dollars)

	Urban	Compact Refill	Compact Greenfield	Standard
SF Large Lot	$220	$213	$223	$249
SF Small Lot	$220	$213	$223	$249
Townhome	$192	$187	$196	$218
Multifamily	$164	$160	$167	$186

Local Revenues

Ongoing annual local revenue assumptions include projected revenues from property taxes, property transfer taxes, and vehicle license fees. The per-unit assumptions vary by housing type and land development category. Assumptions for the Compact land development category also vary by development condition since the per-unit average costs associated with refill and greenfield development differ. Table 12-7 shows the revenue assumptions for California statewide; Table 12-7 shows the revenue assumptions for Southern California Coastal, and Table 12-8 for Southern California Inland (see Figure 12-13 in *Fiscal Impacts Appendix II: Fiscal Impacts Study for Southern California* on page 12-37 for a map of where the boundary is drawn between Coastal and Inland).

Table 12-6: Statewide Per-Unit Local Revenue Assumptions (2010 dollars)

	Urban	Compact Refill	Compact Greenfield	Standard
SF Large Lot	$11,640	$11,230	$9,630	$3,850
SF Small Lot	$9,130	$8,810	$7,570	$3,050
Townhome	$4,020	$4,240	$4,520	$3,320
Multifamily	$2,970	$3,010	$3,270	$1,430

[82] While the 2010 and 2011 Strategic Economics fiscal impacts analyses provided O&M costs for general government services, public safety (police and fire), and community services, UrbanFootprint v 1.0 only uses those costs related to engineering and public works functions. For complete itemized operations and maintenance costs by LDC and unit type, see: Table 21 through Table 25 in *Fiscal Impacts Appendix I: Study for Statewide Scenarios* and Table 67 through Table 69 in *Fiscal Impacts Appendix II: Study for Southern California*.

Table 12-7: Southern California Coastal Per-Unit Local Revenue Assumptions (2008 dollars)

	Urban	Compact Refill	Compact Greenfield	Standard
SF Large Lot	$7,299	$7,881	$6,768	$5,253
SF Small Lot	$5,763	$6,216	$5,349	$4,160
Townhome	$4,936	$5,319	$4,593	$3,575
Multifamily	$3,528	$3,799	$3,276	$2,573

Table 12-8: Southern California Inland Per-Unit Local Revenue Assumptions (2008 dollars)

	Urban	Compact Refill	Compact Greenfield	Standard
SF Large Lot	$4,531	$4,882	$4,210	$3,288
SF Small Lot	$3,596	$3,878	$3,344	$2,618
Townhome	$3,616	$3,898	$3,364	$2,638
Multifamily	$2,462	$2,653	$2,301	$1,818

Fiscal Impact Calculations

Fiscal impacts are calculated on a per unit basis. Infrastructure costs are measured as one-time costs incurred to serve new development. Local revenues and O&M costs, by contrast, are calculated on an annual basis because they are ongoing revenues and costs to cities. Annual O&M and revenue totals reflect the impacts associated with all new growth units built up to a horizon year in that year alone, while cumulative totals reflect the sum of the annual totals for the horizon year and all years prior. [83]

Note also that the fiscal impact calculations are always expressed in constant dollars. As part of advancing chronological modeling capability, UrbanFootprint will be able to account for cost and revenue factors that change over time. The following sections outline the calculations for infrastructure costs, operations and maintenance costs, and revenues as they occur in the current version of the model, and cumulative calculations as they will work when the chronological modeling capability has been added.

Infrastructure Capital Costs

Infrastructure costs are calculated as one-time costs per unit, varying based on building type and LDC/condition.

Annual Infrastructure Costs

Annual infrastructure costs represent the costs associated with new residential development that occurs within a single year. Within UrbanFootprint v1.0, that year is the scenario horizon year which is the year in which all units are assumed to be built. Future versions of UrbanFootprint will include full

[83] Note that UrbanFootprint v1.0 does not include a full chronological accounting of which units are built during which years – and thus for how many years they contribute to the pool of revenue or add to annual operations and maintenance costs. This model advancement, which will entail annual calculations for each year up to a horizon year, is planned for future versions.

chronological accounting that can model the construction of units annually between the base and horizon years. Per-unit cost assumptions are applied to the number of units built by type and land development category/condition, as shown in Equation 12-1.

Equation 12-1: Annual Infrastructure Costs.

$$A_x = \sum_{for\ all\ u} (HH_{ux} * \ CI_u)$$

where:

A_x = Annual infrastructure costs for all growth increment housing units built in year x (in UrbanFootprint v1.0, this is the horizon year)

HH_{ux} = Number of housing units of by housing type/LDC combination u (e.g., Compact refill townhome) built during year x

CI_{ux} = Per-unit infrastructure cost factor for housing type/LDC combination u in year x

If infrastructure cost factors are assumed to remain constant over time, the same equation can be used to calculate cumulative costs (by applying cost factors to total housing units built over the entire time period, rather than units built in a single year only). UrbanFootprint v1.0 estimates cumulative infrastructure costs in this manner.

Cumulative Infrastructure Costs

Note: UrbanFootprint v1.0 does not calculate cumulative costs based on changing rates of development, or changing cost factors, over time. However, the methodology for calculating cumulative costs is included here, as it is ready to be used once a sufficient chronology methodology has been added to UrbanFootprint. At that point in time, the purpose of the cumulative totals calculation will be to add up the sum of all of the one-time annual infrastructure cost calculations.

Cumulative infrastructure costs represent the total costs associated with all new residential development from a base year to a horizon year. Cumulative totals are calculated by adding annual infrastructure costs (A_x) for specified years within a range, as shown in Equation 12-2.

Equation 12-2: Cumulative Capital Infrastructure Costs (Not used in UrbanFootprint v1.0).

$$I_y = \sum_{2035}^{x=2005} A_x$$

where:

I_y = Cumulative total infrastructure costs for all growth increment housing units built *between* year x and year y. (e.g., total costs by 2035 for all units built between 2005 and 2035)

A_x = Annual infrastructure costs for all growth increment housing units built in year x

Operations and Maintenance Costs

Local operations and maintenance (O&M) costs are calculated as a function of annual cost factors, which are applied to new households on a per capita basis. Total annual costs grow as more units are built.

Annual Operations and Maintenance Costs

Annual O&M costs represent the costs associated with operating and maintaining public infrastructure to serve all of the new residential development built between a base year and a given year, in that given year. Per-unit cost assumptions are applied to the number of units built by type and LDC/condition as shown in Equation 12-3. Horizon-year annual costs are calculated in this manner.

Equation 12-3: Annual O&M costs in any year for new units built to that year.

$$Y_x = \sum_{for\ all\ u} (HH_{ux} * CI_u)$$

where:

A_x = Annual O&M costs for all growth increment housing units built between base year and year x

HH_{ux} = Number of housing units of by housing type/LDC combination u (e.g., Compact refill townhome) built between base year and year x

CI_{ux} = Per-unit O&M cost factor for housing type/LDC combination in year x

Cumulative Operations and Maintenance Costs

Cumulative O&M costs represent the sum total of annual O&M costs leading up to a specified horizon year. Cumulative totals are calculated by adding total annual O&M costs (A_x) for specified years within a range, as shown in Equation 12-4.

Equation 12-4: Cumulative Annual O&M costs (Not used in UrbanFootprint v1.0).

$$OM_y = \sum_{2035}^{x=2005} A_x$$

where:

OM_y = Cumulative total O&M costs for all units built *between* year x and year y. (e.g., total costs by 2035 for all units built between 2005 and 2035)

A_x = Total O&M costs in year x

Local Revenues

Local revenues are calculated based on tax revenues generated from new residential growth on a per unit basis. Total annual revenues grow each year as more units are built.

Annual Revenues

Annual revenues represent the revenues generated by all new residential development built between a base year and a horizon year, in a given year. Per-unit revenue assumptions are applied to the number of units built by type and LDC/condition as shown in Equation 12-5. Horizon-year annual costs are calculated in this manner.

Equation 12-5: Annual revenues in any year for new units built to that year.

$$Y_x = \sum_{for\ all\ u} (HH_{ux} * CI_u)$$

where:

A_x = Annual revenues for all growth increment housing units built between base year and year x

HH_{ux} = Number of housing units of by housing type/LDC combination u (e.g., Compact refill townhome) built between base year and year x

CI_{ux} = Per-unit revenue factor for housing type/LDC combination in year x

Cumulative Revenues

Cumulative revenues represent the sum total of annual revenues leading up to a specified horizon year. Cumulative totals are calculated by adding total annual revenues (A_x) for specified years within a range, as shown in Equation 12-6.

Equation 12-6: Cumulative Annual revenues (Not used in UrbanFootprint v1.0).

$$R_y = \sum_{2035}^{x=2005} A_x$$

where:

R_y = Cumulative total revenues for all units built *between* year x and year y. (e.g., total costs by 2035 for all units built between 2005 and 2035)

A_x = Total revenues in year x

Fiscal Impacts Appendix I: Study for Statewide Scenarios

Strategic Economics was retained by Calthorpe Associates for a study in 2010, funded by the Climate Works and Energy Foundations, to develop factors for use in estimating the local fiscal impacts of statewide land use scenarios. This appendix summarizes the methodology, assumptions, and data sources used to develop the factors for local infrastructure capital costs, operations and maintenance costs, and revenues.

Fiscal impact analysis typically measures future revenues and costs associated with new growth and development in order to assess the overall impact to local government. Several studies[84] have suggested that municipal service costs for compact, infill development are generally lower than for low-density "sprawl" development. Many of the studies cited in "smart growth" literature are focused on showing that compact growth can significantly reduce the need for new infrastructure and services by directing development to places with existing capacity, and allowing for "economies of scale" for certain types of public infrastructure, such as roads and sewers.[85] A number of studies measuring service costs and revenues compare "sprawl" development in ex-urban or unincorporated areas to compact developments within established urban areas.[86] Such a comparison does not tell a complete story of why service costs and revenues may differ because each of the place types has differing governmental and fiscal structure. Neither Calthorpe Associates nor Strategic Economics are aware of recent studies that compare the fiscal impacts of growth in established "sprawl" cities versus infill urban places, and extrapolate the findings to a larger statewide scale.

In order to measure the fiscal impacts of various land development patterns, Strategic Economics measured the municipal costs and revenues incurred from each individual household or dwelling unit. This methodology allowed the comparison of different development patterns rather than land use plans associated with a specific place.

The analysis considered the following costs and revenues:

1. Capital costs of building new infrastructure and facilities
2. Operations and maintenance (O&M) costs for facilities and provision of municipal services
3. Primary sources of local tax revenues (property taxes, sales taxes, and vehicle license fees).

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[84] William Coyne (2003), The Fiscal Cost of Sprawl: How Sprawl Contributes to Local Governments' Budget Woes, Environment Colorado Research & Policy Center at www.impactfees.com/publications%20pdf/fiscalcostofsprawl12_03.pdf.

Todd Litman (2005), Understanding Smart Growth Savings: What We Know About Public Infrastructure and Service Cost Savings, And How They are Misrepresented By Critics, Victoria Transport Policy Institute (www.vtpi.org); at www.vtpi.org/sg_save.pdf.

[85] Reid Ewing, Rolf Pendall and Don Chen (2002), Measuring Sprawl and Its Impacts, Smart Growth America (www.smartgrowthamerica.org).

[86] Robert Burchell, et al (2002), The Costs of Sprawl – 2000, TCRP Report 74, Transportation Research Board (www.trb.org); at http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_74-a.pdf.

Due to the fact that schools are not primarily funded directly by cities, the impact to school districts was not measured.

Finally, because the fiscal impacts study only measured the impact of residential development, Strategic Economics netted out all costs and revenues associated with employment uses and attributed only those costs and revenues associated with residential uses.

Fiscal Impacts Study Methodology

Infrastructure Costs

Infrastructure costs, or the capital costs of building public infrastructure and facilities to serve new development, are one-time costs. Strategic Economics estimated infrastructure costs based on development impact fees assessed in various cities. Development impact fees represent the capital costs to cities to provide the infrastructure needed to serve new development. In California these fees are typically calculated to capture the full costs of infrastructure investments triggered by new residential development. Cities may reduce fees for commercial development but are less likely to subsidize the infrastructure costs associated with residential development. The infrastructure costs considered in this analysis include the following major categories:

- Streets and Transportation, or the costs of new roads required to serve development;
- Parks, or the costs of parks and recreation facilities required to serve development;
- Sewage/Wastewater, or the costs of wastewater treatment facilities required to serve development; and
- Water, or the costs of water treatment required to serve development.

The above categories cover the most commonly incurred infrastructure costs associated with new development. Some cities may charge development impact fees for other categories of infrastructure, including General Government, Police, Fire, and Libraries. Those categories are not charged consistently and typically make up a smaller portion of infrastructure costs associated with new development, and were therefore excluded from this analysis.

Operations and Maintenance Costs

The operations and maintenance costs (O&M) represent the cost of providing ongoing services to new development. Strategic Economics calculated O&M costs on a per capita basis based on the General Fund expenditures of the representative cities included in the analysis. O&M costs are broken out into the following major categories:

- General Government: including administrative and legislative functions.
- Public Safety: including fire and police services.
- Community Services: including library and recreation services.
- Engineering and Public Works: including only General Fund public works functions.

Community development and other categories often paid with from designated revenues (such as building permit fees) were excluded. Similarly, debt service costs were excluded from the analysis.

Revenues
Revenues are calculated on a per capita or household basis based on statewide averages for some revenue factors and on property value calculations. The methodology for deriving revenue estimates is described in further detail in the Base Assumptions section, below.

Land Development Categories
Strategic Economics identified analog cities to correspond with Land Development Categories (LDCs), generally based on a correspondence with the vehicle miles traveled (VMT) standards for LDCs described above. The LDCs used for the fiscal analysis are as follows:

Standard is the least intense LDC and is represented by suburban and stand-alone cities that have lower densities and fewer nonresidential uses. Cities and places examined by the fiscal impacts study in the Standard category include:

- Coachella;
- Davis;
- El Centro;
- Fairfield;
- Lompoc;
- Modesto;
- Rancho Cucamonga;
- San Diego – Navajo Planning Area;
- Santa Rosa – Southeast Plan Area;
- Stanislaus County (unincorporated); and
- Tracy.

Compact – Greenfield is less intense than Urban, but is a walkable development pattern with a mix of single-family small-lot, single-family attached/townhome and multi-family units in addition to a mix of nonresidential uses. A selection of specific plan areas were used in the fiscal impacts study to represent the Compact – Greenfield LDC, including:

- East Garrison (specific plan area);
- Hercules;
- Hunters Point in San Francisco (specific plan area);
- Tustin (specific plan area); and
- Napa Pipe (specific plan area).

Compact – Refill, like the Compact – Greenfield LDC, is less intense than Urban, and is represented by largely built out cities with a mix of housing types and nonresidential uses. Cities and places examined for the purposes of the fiscal impacts study in the Compact - Refill category include:

- Palo Alto;
- Pasadena;
- San Diego - Greater North Park Planning Area;

- San Mateo;
- Santa Cruz; and
- Santa Rosa – Downtown.

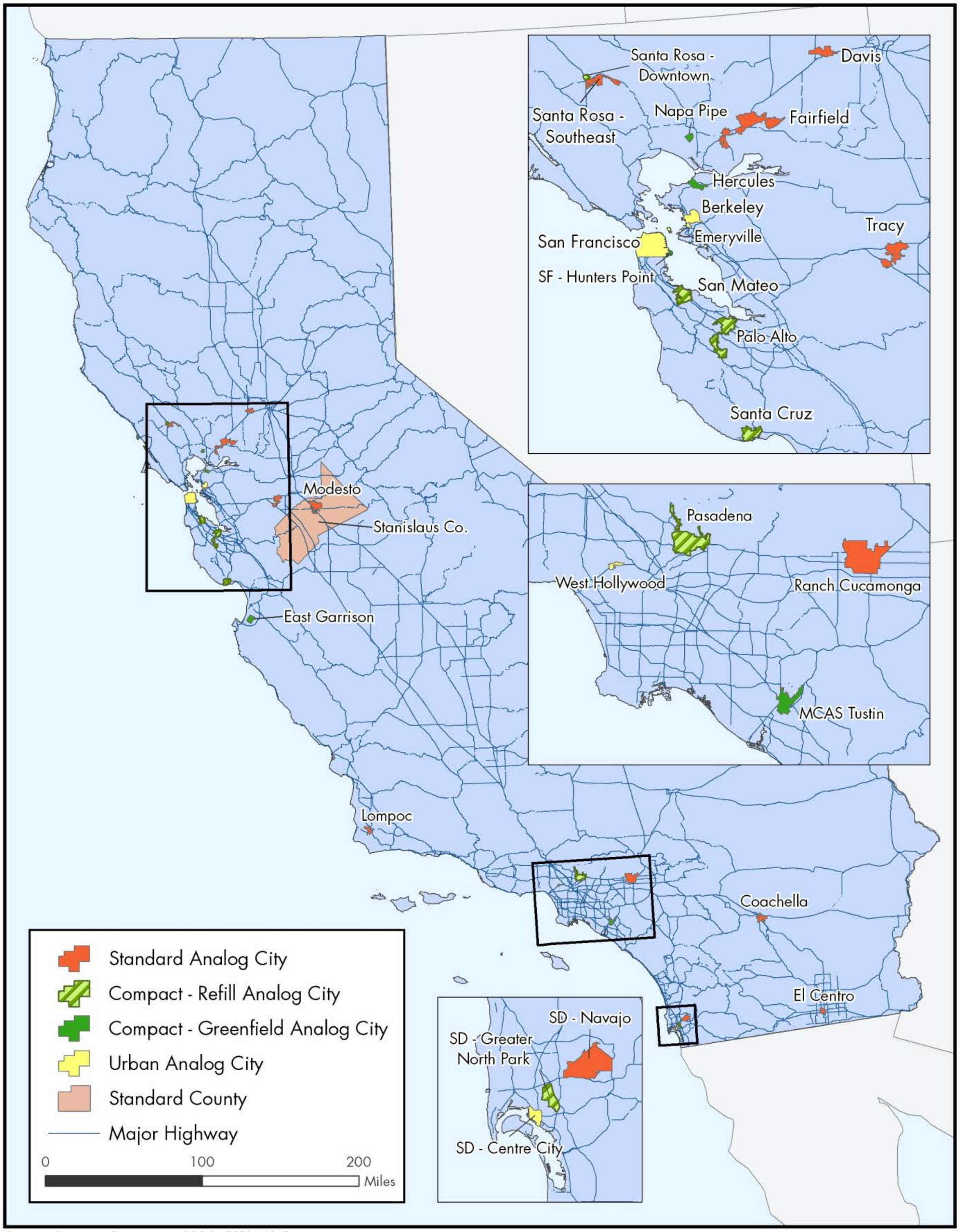
Urban is the most intense and most mixed of the LDCs. For the purposes of the fiscal analysis, major California cities and city centers were used to represent the Urban LDC, including:

- Emeryville;
- Berkeley;
- San Diego - Centre City Planning Area;
- San Francisco; and
- West Hollywood.

Figure 12-1 maps the analogue cities used by Strategic Economics to represent the LDCs in the 2010 fiscal impacts analysis study.

Figure 12-2 includes aerials of cities depicting the LDCs.

Figure 12-1: Analogue Cities Representing Land Development Categories



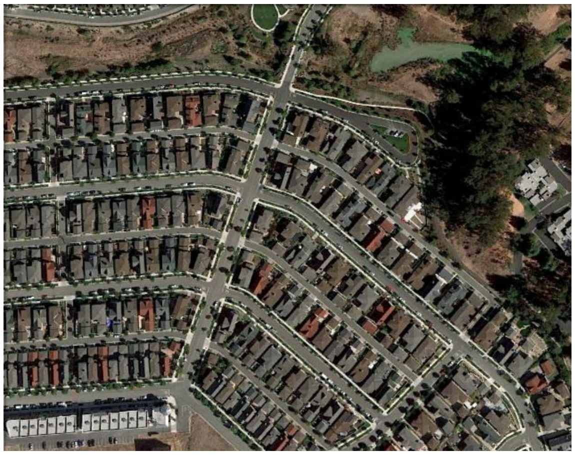
Source: Strategic Economics, 2010; ESRI; US Census

Figure 12-2: Aerials Depicting Land Development Categories

Standard

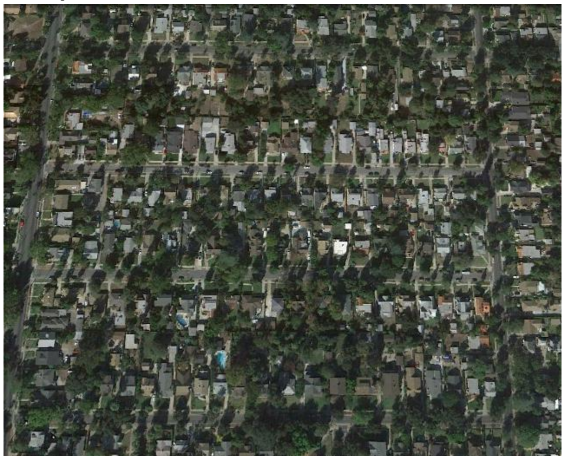
Coachella, CA

Compact-Greenfield



Hercules, CA

Compact-Refill



Pasadena, CA

Urban

San Francisco, CA

Source: Google Earth, 2010

Limitations of data/methodology

This methodology allows the generalization of fiscal impacts across the entire state, but it has its limitations. The 2010 fiscal impact analysis was limited by scope to the impacts associated with households and did not consider the impacts of nonresidential development. Further, the analysis only considered General Fund costs and revenues and did not measure the impacts of development on services or infrastructure that may be paid for from other funding sources. The analysis did not consider other economic benefits often attributed to "smart growth," such as lower transportation costs for households and businesses, improved access to jobs or housing for low-income people, and enhanced economic productivity and innovation. Because the analysis was meant to compare the relative impacts of the LDCs and was not intended to determine the net fiscal impact of a land use alternative to a specific municipality, it did not consider every source of revenue and expenditure. Rather, the analysis focused on the major categories of cost and revenue for California cities.

Furthermore, due to the wide variability in the property tax revenue structure for cities in California it was not possible to calculate the net fiscal impacts at the state level under each LDC. A similar analysis conducted for a smaller set of cities or for a specific region could allow for the calculation of net fiscal impacts.

Base Assumptions

As with all fiscal impact analyses, the assumptions drive the results. Strategic Economics created its assumptions based upon available data population and housing characteristics, municipal revenue and cost factors, real estate market indicators, and commonly applied fiscal impact analysis standards. The 2010 fiscal impacts analysis used current averages for costs and revenues on a per capita basis. The per capita cost and revenue factors were then applied to the assumptions associated with a specific housing type + LDC combination.

Base Year

The 2010 fiscal impacts analysis was based on the year 2009. When 2009 data was not available, assumptions were adjusted to 2009 dollars.

Land Use Assumptions

Strategic Economics worked with Calthorpe Associates to develop a list of cities and places to represent the four LDCs used in the fiscal impacts module.

For residential units, fiscal impacts are calculated for four housing types:

- Single Family Small Lot Detached (SF Small Lot);
- Single Family Large Lot Detached (SF Large Lot);
- Single Family Attached/Townhome (Townhome); and
- Multi-Family.

Table 12-9 shows the assumptions for average unit size (in square feet) for the four housing types.

Table 12-9: Average Unit Size (Square Feet), by Housing Type

Housing Type	Average Unit Size (Square Feet)	Source
SF Small Lot Detached	1,700	US Census SOC 2009 Microdata
SF Large Lot Detached	3,100	US Census SOC 2009 Microdata
SF Attached/Townhome	1,650	US Census SOC 2009 Microdata
Multi-Family	1,150	US Census SOC 2009 Microdata

The unit size for the SF Small Lot housing type was calculated based on the 25th percentile of new home sizes from US Census Survey of Construction (SOC) data in 2009, while the SF Large Lot unit size was based on the 75th percentile. Townhome and Multi-Family unit sizes are averages for those housing types.

Table 12-10 shows the assumptions for average unit lot size for the four housing types.

Table 12-10: Per Unit Average Lot Size (Square Feet), by Housing Type

Housing Type	Gross Lot Size per Unit (Square Feet)	Source
SF Small Lot Detached	5,125	US Census SOC 2009 Microdata
SF Large Lot Detached	12,875	US Census SOC 2009 Microdata
SF Attached/Townhome	2,300	US Census SOC 2009 Microdata
Multi-Family	1,089	Calthorpe Associates/Strategic Economics

Similar to assumptions for unit size, the lot size for SF Small Lot is the 25th percentile and the lot size for SF Large Lot is the 75th percentile for new home lots in 2009. Townhome lot size is the average for that housing type based on the SOC. The lot size for Multi-Family is an assumption for density for that product type based on professional experience.

Based on the lot sizes described above, Strategic Economics made assumptions on average net dwelling units per acre by housing type, as shown in Table 12-11.

Table 12-11: Average Density (net dwelling units per acre) Assumptions by Housing Type

Housing Type	Dwelling Units per Acre	Source
SF Small Lot Detached	8.50	US Census SOC 2009 Microdata
SF Large Lot Detached	3.38	US Census SOC 2009 Microdata
SF Attached/Townhome	18.94	US Census SOC 2009 Microdata
Multi-Family	40	Calthorpe Associates/Strategic Economics

Property Values

To calculate property values, Strategic Economics collected market data for the housing types in the places chosen to represent the LDCs. The following set of tables (Table 12-12 through Table 12-15) show the average housing values by type for each of the LDCs considered in the analysis.

Table 12-12: Average Housing Values by Type – Standard

Housing Type	Value	Source
SF Small Lot Detached	$281,700	DQ News/CBIA/Hanley-Woods Reports
SF Large Lot Detached	$361,752	DQ News/CBIA/Hanley-Woods Reports
SF Attached/Townhome – For Sale	$308,300	DQ News/CBIA/Hanley-Woods Reports
Multi-Family – For Sale	$176,300	DQ News/CBIA/Hanley-Woods Reports
SF Attached/Townhome – Rental	$314,000	Real Facts/Marcus Millichap
Multi-Family - Rental	$109,000	Real Facts/Marcus Millichap

Table 12-13: Average Housing Values by Type – Compact-Greenfield

Housing Type	Value	Source
SF Small Lot Detached	$730,200	DQ News/CBIA/Hanley-Woods Reports
SF Large Lot Detached	$935,394	DQ News/CBIA/Hanley-Woods Reports
SF Attached/Townhome – For Sale	$427,000	DQ News/CBIA/Hanley-Woods Reports
Multi-Family – For Sale	$441,284	DQ News/CBIA/Hanley-Woods Reports
SF Attached/Townhome – Rental	$435,000	Real Facts/Marcus Millichap
Multi-Family - Rental	$272,000	Real Facts/Marcus Millichap

Table 12-14: Average Housing Values by Type – Compact-Refill

Housing Type	Value	Source
SF Small Lot Detached	$853,800	DQ News/CBIA/Hanley-Woods Reports
SF Large Lot Detached	$1,093,742	DQ News/CBIA/Hanley-Woods Reports
SF Attached/Townhome – For Sale	$399,000	DQ News/CBIA/Hanley-Woods Reports
Multi-Family – For Sale	$403,700	DQ News/CBIA/Hanley-Woods Reports
SF Attached/Townhome – Rental	$406,000	Real Facts/Marcus Millichap
Multi-Family - Rental	$249,000	Real Facts/Marcus Millichap

Table 12-15: Average Housing Values by Type – Urban

Housing Type	Value	Source
SF Small Lot Detached	$885,600	DQ News/CBIA/Hanley-Woods Reports
SF Large Lot Detached	$1,134,476	DQ News/CBIA/Hanley-Woods Reports
SF Attached/Townhome – For Sale	$377,200	DQ News/CBIA/Hanley-Woods Reports
Multi-Family – For Sale	$397,900	DQ News/CBIA/Hanley-Woods Reports
SF Attached/Townhome – Rental	$384,000	Real Facts/Marcus Millichap
Multi-Family - Rental	$245,000	Real Facts/Marcus Millichap

In order to calculate a blended value representing for sale and rental units for the Townhome and Multi-family housing types, Strategic Economics collected data on the percentage of new units built in California as for sale units versus rental units. The property value for those housing types was then derived from a weighted average of the values of for sale and rental units based on the percentages shown in Table 12-16 through

Table 12-19.

Table 12-16: Calculated Value for Rentals and For Sale Units - Standard

SF Attached/Townhome		Source
% For Sale Units	73.2%	US Census PUMS 2009
% Rental Units	26.8%	US Census PUMS 2009
Weighted Value	$310,000	
Multi-Family		
% For Sale Units	19.3%	US Census PUMS 2009
% Rental Units	80.7%	US Census PUMS 2009
Weighted Value	$122,000	

Table 12-17: Calculated Value for Rentals and For Sale Units - Compact-Greenfield

SF Attached/Townhome		Source
% For Sale Units	73.2%	US Census PUMS 2009
% Rental Units	26.8%	US Census PUMS 2009
Weighted Value	$429,000	
Multi-Family		
% For Sale Units	19.3%	US Census PUMS 2009
% Rental Units	80.7%	US Census PUMS 2009
Weighted Value	$305,000	

Table 12-18: Calculated Value for Rentals and For Sale Units - Compact-Refill

SF Attached/Townhome		Source
% For Sale Units	73.2%	US Census PUMS 2009
% Rental Units	26.8%	US Census PUMS 2009
Weighted Value	$401,000	
Multi-Family		
% For Sale Units	19.3%	US Census PUMS 2009
% Rental Units	80.7%	US Census PUMS 2009
Weighted Value	$279,000	

Table 12-19: Calculated Value for Rentals and For Sale Units - Urban

SF Attached/Townhome		Source
% For Sale Units	73.2%	US Census PUMS 2009
% Rental Units	26.8%	US Census PUMS 2009
Weighted Value	$379,000	
Multi-Family		
% For Sale Units	19.3%	US Census PUMS 2009
% Rental Units	80.7%	US Census PUMS 2009
Weighted Value	$275,000	

Household Assumptions

Strategic Economics gathered data on population, employment, and household size and composition in order to make a series of assumptions on the service base. The service base is the population served by a municipality. Because this analysis did not consider the impacts of employees, Strategic Economics netted out costs and revenues associated with employment uses and attributed only those costs and revenues associated with residential uses to the housing types described above.[87]

As described above, many of the costs and revenues in the fiscal analysis were calculated based on the net increase in population resulting from the household types analyzed. Therefore Strategic Economics collected data from the US Census Public-Use Microdata Samples (PUMS) 2009 files on persons per household by housing type, as shown in Table 12-20.

Table 12-20: Average Household Size, by Housing Type

Average Density	Avg Household Size	Source
Single Family Detached	2.97	PUMS 2009
Single Family Attached/Townhome	2.60	PUMS 2009
Multi-Family	2.22	PUMS 2009

Results of the 2010 Fiscal Impacts Analysis Study

Infrastructure Costs

The results for the infrastructure cost analysis are summarized below. Table 12-21 shows how many example impact fees were considered in calculating the infrastructure costs by LDC. See *Fiscal Impacts Appendix II: Fiscal Impacts Study for Southern California* on page 12-37 for additional results from studies of jurisdictions in Southern California; future model improvements will include further study of the costs associated with compact refill development.

[87] To determine O&M costs associated with residential uses only Strategic Economics applied a “Service Population Factor” to costs. The residential service population was assumed to have a 1.0 factor, while the employment service population was assumed to have a 0.3 factor. The costs attributed to employment uses were then subtracted from total costs and revenues.

Table 12-21: Number of Entries by Fee Type, by LDC (Source: Strategic Economics, 2010.)

Infrastructure Category	Standard	Compact-Greenfield	Compact-Refill	Urban
Streets and	11	4	6	3
Parks	11	2	4	2
Sewage/Wastewater	5	4	3	3
Water	5	3	1	3

Table 12-22 through Table 12-25 show the average impact fees for selected infrastructure categories by LDC.

Table 12-22: Single Family Large Lot Average Impact Fees by LDC (Source: Strategic Economics, 2010.)

Infrastructure Category	Standard	Compact-Greenfield	Compact-Refill	Urban
Streets and Transportation	$5,744	$5,584	$3,231	$838
Parks	$4,831	$9,551	$4,442	$4,667
Sewage/Wastewater	$6,138	$5,382	$6,100	$1,534
Water	$5,052	$3,182	$5,512	$5,371
Total	$21,765	$23,699	$19,286	$12,410

Table 12-23: Single Family Small Lot Average Impact Fees, by LDC (Source: Strategic Economics, 2010.)

Infrastructure Category	Standard	Compact-Greenfield	Compact-Refill	Urban
Streets and Transportation	$5,650	$5,584	$3,231	$838
Parks	$4,663	$9,551	$3,324	$4,667
Sewage/Wastewater	$6,138	$5,382	$6,100	$1,534
Water	$5,052	$3,182	$5,512	$3,626
Total	$21,504	$23,699	$18,167	$10,665

Table 12-24: Single Family Attached Average Impact Fees, by LDC (Source: Strategic Economics, 2010.)

Infrastructure Category	Standard	Compact-Greenfield	Compact-Refill	Urban
Streets and Transportation	$5,650	$5,584	$2,918	$838
Parks	$4,561	$9,551	$3,334	$4,667
Sewage/Wastewater	$6,138	$5,382	$6,100	$1,534
Water	$5,052	$3,182	$5,512	$3,626
Total	$21,401	$23,699	$17,864	$10,665

Table 12-25: Multi-Family Average Impact Fees, by LDC (Source: Strategic Economics, 2010.)

Infrastructure Category	Standard	Compact-Greenfield*	Compact-Refill	Urban
Streets and Transportation	$4,553	$4,174	$2,181	$671
Parks	$3,815	$7,928	$2,664	$3,639
Sewage/Wastewater	$3,867	$4,932	$5,591	$912
Water**	$2,805	$1,061	$2,520	$3,359
Total	$15,040	$16,696	$12,956	$8,581

** Multi-Family Compact-Greenfield Impact Fees are based on the proportional cost difference for Townhomes between Compact-Refill and Compact-Greenfield development types.*
*** There are only 4 entries for Standard Multi-Family water impacts fees.*

Table 12-26 sums the infrastructure costs as represented by the impact fees on a per acre basis by housing type and LDC.

Table 12-26: Per Acre Impact Fees, by Housing Type and LDC (Source: Strategic Economics, 2010.)

	Standard	Compact-Greenfield	Compact-Refill	Urban
Single Family Large-Lot	$73,639	$80,181	$65,249	$41,987
Single Family Small-Lot	$182,771	$201,429	$154,415	$90,649
Single Family Attached	$405,318	$448,837	$338,319	$201,989
Multi-Family	$601,590	$667,832	$518,250	$343,239

Operations and Maintenance Costs

Operations and maintenance (O&M) costs are based on actual General Fund expenditures in the same sample cities (with noted exceptions) included in the infrastructure cost calculations. Strategic Economics used city budget documents and Comprehensive Annual Financial Reports (CAFRs) to compile General Fund costs for major service areas for the cities included in the analysis.

San Francisco was excluded from O&M analysis because it is a county as well as a city and therefore provides county-level services (for example healthcare, sheriff, and jail services) that are not typical city services. The City of Coachella was also excluded because it contracts out for key city services, including public safety and is therefore not comparable to the other cities. Some of the other cities included in the analysis contract out for some services, but were found to be “full-service” cities because of the level of service provided.

General Fund costs for general government, fire services, police services, community services, and public works for each city were divided by the service base for that city to calculate a per capita O&M cost. Those costs for each city were then averaged by LDC to obtain the per capita cost assumptions for the fiscal model. Table 12-27 shows the per capita costs for O&M by major service category and LDC. Strategic Economics applied the average household size assumptions shown in Table 12-20 to arrive at the average costs per household. Table 12-28 through

Table 12-31 show the same O&M costs on a household basis by housing type and LDC. Table 12-32 through Table 12-35 show the same O&M costs on a per acre basis by housing type and LDC.

Table 12-27: Per Capita Operations and Maintenance Costs by Development Type (Source: Strategic Economics, 2010.)

Development Type	Standard*	Compact-Greenfield	Compact-Refill	Urban**
General Government	$110	$125	$172	$375
Public Safety	$360	$286	$490	$583
Community Services	$137	$76	$214	$296
Engineering and Public Works	$172	$164	$96	$162
Total	$779	$650	$973	$1,416

** Standard does not include the City of Coachella because it is not a full-service city and contracts for key services.*

*** Urban does not include San Francisco because it is a City and County.*

Table 12-28: Single Family Large-Lot Per Household Operations and Maintenance Costs, by LDC (Source: Strategic Economics, 2010.)

	Standard*	Compact-Greenfield	Compact-Refill	Urban**
General Government	$328	$370	$512	$1,113
Public Safety	$1,068	$848	$1,456	$1,732
Community Services	$408	$225	$634	$880
Engineering and Public Works	$510	$486	$286	$480
Total	$2,314	$1,930	$2,888	$4,204

Table 12-29: Single Family Small-Lot Per Household Operations and Maintenance Costs, by LDC (Source: Strategic Economics, 2010.)

	Standard*	Compact-Greenfield	Compact-Refill	Urban**
General Government	$328	$370	$512	$1,113
Public Safety	$1,068	$848	$1,456	$1,732
Community Services	$408	$225	$634	$880
Engineering and Public Works	$510	$486	$286	$480
Total	$2,314	$1,930	$2,888	$4,204

Table 12-30: Single Family Attached / Townhome Per Household Operations and Maintenance Costs, by LDC (Source: Strategic Economics, 2010.)

	Standard*	Compact-Greenfield	Compact-Refill	Urban**
General Government	$287	$324	$448	$974
Public Safety	$935	$743	$1,275	$1,516
Community Services	$357	$197	$555	$770
Engineering and Public Works	$447	$426	$250	$420
Total	$2,026	$1,689	$2,529	$3,680

Table 12-31: Multi-Family Per Household Operations and Maintenance Costs, by LDC (Source: Strategic Economics, 2010.)

	Standard*	Compact-Greenfield	Compact-Refill	Urban**
General Government	$245	$277	$383	$832
Public Safety	$799	$634	$1,088	$1,294
Community Services	$305	$168	$474	$657
Engineering and Public Works	$381	$363	$214	$359
Total	$1,730	$1,442	$2,159	$3,143

** Standard does not include the City of Coachella because it is not a full-service city and contracts for key services.*

*** Urban does not include San Francisco because it is a City and County.*

Table 12-32: Single Family Large-Lot Per Acre Operations and Maintenance Costs, by LDC (Source: Strategic Economics, 2010.)

	Standard*	Compact-Greenfield	Compact-Refill	Urban**
General Government	$1,110	$1,252	$1,733	$3,765

Public Safety	$3,615	$2,871	$4,927	$5,859
Community Services	$1,380	$762	$2,146	$2,976
Engineering and Public Works	$1,726	$1,644	$967	$1,624
Total	$7,830	$6,529	$9,773	$14,224

Table 12-33: Single Family Small-Lot Per Acre Operations and Maintenance Costs, by LDC (Source: Strategic Economics, 2010.)

	Standard*	Compact-Greenfield	Compact-Refill	Urban**
General Government	$2,788	$3,144	$4,354	$9,459
Public Safety	$9,081	$7,212	$12,377	$14,719
Community Services	$3,466	$1,915	$5,391	$7,476
Engineering and Public Works	$4,336	$4,131	$2,429	$4,080
Total	$19,671	$16,402	$24,551	$35,734

Table 12-34: Single Family Attached / Townhome Per Acre Operations and Maintenance Costs, by LDC (Source: Strategic Economics, 2010.)

	Standard*	Compact-Greenfield	Compact-Refill	Urban**
General Government	$5,438	$6,134	$8,494	$18,451
Public Safety	$17,714	$14,067	$24,142	$28,712
Community Services	$6,762	$3,736	$10,515	$14,583
Engineering and Public Works	$8,458	$8,059	$4,738	$7,959
Total	$38,372	$31,995	$47,890	$69,704

Table 12-35: Multi-Family Per Acre Operations and Maintenance Costs, by LDC (Source: Strategic Economics, 2010.)

	Standard*	Compact-Greenfield	Compact-Refill	Urban**
General Government	$9,807	$11,061	$15,318	$33,273
Public Safety	$31,944	$25,368	$43,537	$51,777
Community Services	$12,194	$6,737	$18,963	$26,298
Engineering and Public Works	$15,252	$14,533	$8,545	$14,353
Total	$69,198	$57,699	$86,363	$125,701

** Standard does not include the City of Coachella because it is not a full-service city and contracts for key services.*

*** Urban does not include San Francisco because it is a City and County.*

Revenue

Strategic Economics calculated the potential revenues from property tax revenues, sales tax revenues, and vehicle license fees generated by new housing units under each development pattern and for each housing type. Property tax revenues were calculated based on 2009 market values for new construction housing units in each of the cities included in the analysis, as shown in Table 12-12 through Table 12-15[88].

Local property tax revenues are shared among numerous beneficiaries, including the City's General Fund, special districts, school districts, and the County. Each jurisdiction has a unique revenue sharing

[88] Data sources included Dataquick, Realfacts, Hanley Wood Market Intelligence, and California Infill Builders Association.

arrangement, and the General Fund's share of the property tax revenues varies from city to city. In order to simplify the analysis, Strategic Economics estimated the local property tax revenues at one percent of total assessed value, without further allocating the funds to individual agencies and districts.

Property Transfer Tax is collected on the sale price at time of sale of a unit. A holding period is the length of time between changes in ownership of property. The holding period is used to calculate property transfer taxes (i.e. property sales) and boosts in property values when Proposition 13-limited values increase upon property sale. Strategic Economics assumed a seven-year holding period for single family residential units, and a 5 year period for multifamily, respectively.

Vehicle license fees were estimated based on a standard formula for calculating revenues per household and per capita, and applying the average household size assumption. Strategic Economics calculated VLF revenues at $2.65 per capita.

Sales tax revenues are calculated based on statewide retail store spending and do not reflect variable spending resulting from income variations and retail mix. The revenues are calculated as 0.75 percent of sales, representing the revenues retained by cities for general use, and not other local program specific sales taxes or those assessed regionally or statewide.

Table 12-36: Vehicle License Fee Calculations (Sources: California City Finance Website; PUMS 2009.)

Item	Value
Per Capita VLF	$2.65
Per Household VLF Revenue – Single Family Detached	$7.87
Per Household VLF Revenue – Single Family Attached	$6.89
Per Household VLF Revenue – Multifamily	$5.88

Table 12-37: Sales Tax Calculations (Sources: California State Board of Equalization; California Department of Finance; Strategic Economics 2010.)

Item	Value
Total Retail Store Taxable Sales	$357,318,427,000
Total Households	13,442,989
Per Household Taxable Sales	$26,580
Municipal Sales Tax*	0.75%
Per Household Annual Sales Tax Revenue	$199

*Includes only the .75% sales tax retained by cities for general use and not other local program specific sales taxes or those assessed regionally or statewide.

Table 12-38: Property Transfer Tax Calculations – Standard (Sources: DQ News; CBIA: Hanley-Woods; California State Board of Equalization; Strategic Economics, 2010.)

Item	SF Large Lot	SF Small Lot	SF Attached	Multifamily
Sales Price	$361,752	$281,700	$310,000	$122,000

Typical Property Transfer	0.055%	0.055%	0.055%	0.055%
Average Holding Period (Years)	7	7	10	10
Per Household Annual Property Transfer Tax Revenue	$28	$22	$17	$7

Table 12-39: Property Transfer Tax Calculations – Compact-Greenfield (Sources: DQ News; CBIA: Hanley-Woods; California State Board of Equalization; Strategic Economics, 2010.)

Item	SF Large Lot	SF Small Lot	SF Attached	Multifamily
Sales Price	$935,394	$730,200	$429,000	$305,000
Typical Property Transfer Rate*	0.055%	0.055%	0.055%	0.055%
Average Holding Period (Years)	7	7	10	10
Per Household Annual Property Transfer Tax Revenue	$73	$57	$24	$17

Table 12-40: Property Transfer Tax Calculations – Compact-Refill (Sources: DQ News; CBIA: Hanley-Woods; California State Board of Equalization; Strategic Economics, 2010.)

Item	SF Large Lot	SF Small Lot	SF Attached	Multifamily
Sales Price	$1,093,742	$853,800	$401,000	$279,000
Typical Property Transfer Rate*	0.055%	0.055%	0.055%	0.055%
Average Holding Period (Years)	7	7	10	10
Per Household Annual Property Transfer Tax Revenue	$86	$67	$22	$15

Table 12-41: Property Transfer Tax Calculations – Urban (Sources: DQ News; CBIA: Hanley-Woods; California State Board of Equalization; Strategic Economics, 2010.)

Item	SF Large Lot	SF Small Lot	SF Attached	Multifamily
Sales Price	$1,134,476	$885,600	$379,000	$275,000
Typical Property Transfer Rate*	0.055%	0.055%	0.055%	0.055%
Average Holding Period (Years)	7	7	10	10
Per Household Annual Property Transfer Tax Revenue	$89	$70	$21	$15

*General Law cities are limited to a Property Transfer Tax Rate of $0.55 per $1,000 in property value or 0.055%. Although Chartered cities can charge a higher Property Transfer Tax Rate, it is conservative to use the lower rate.

Table 12-42: Property Tax Calculations – Standard (Sources: DQ News; CBIA: Hanley-Woods; California State Board of Equalization; Strategic Economics, 2010.)

Item	SF Large Lot	SF Small Lot	SF Attached	Multifamily
Assessed Value	$361,752	$281,700	$310,000	$122,000
Property Tax Rate*	1.00%	1.00%	1.00%	1.00%
Per Household Annual Property Transfer Tax Revenue	$3,618	$2,817	$3,100	$1,220

Table 12-43: Property Tax Calculations - Compact-Greenfield (Sources: DQ News; CBIA: Hanley-Woods; California State Board of Equalization; Strategic Economics, 2010.)

Item	SF Large Lot	SF Small Lot	SF Attached	Multifamily
Assessed Value	$935,394	$730,200	$429,000	$305,000
Property Tax Rate*	1.00%	1.00%	1.00%	1.00%
Per Household Annual Property Transfer Tax Revenue	$9,354	$7,302	$4,290	$3,050

Table 12-44: Property Tax Calculations - Compact-Refill (Sources: DQ News; CBIA: Hanley-Woods; California State Board of Equalization; Strategic Economics, 2010.)

Item	SF Large Lot	SF Small Lot	SF Attached	Multifamily
Assessed Value	$1,093,742	$853,800	$401,000	$279,000
Property Tax Rate*	1.00%	1.00%	1.00%	1.00%
Per Household Annual Property Transfer Tax Revenue	$10,937	$8,538	$4,010	$2,790

Table 12-45: Property Tax Calculations – Urban (Sources: DQ News; CBIA: Hanley-Woods; California State Board of Equalization; Strategic Economics, 2010.)

Item	SF Large Lot	SF Small Lot	SF Attached	Multifamily
Assessed Value	$1,134,476	$885,600	$379,000	$275,000
Property Tax Rate*	1.00%	1.00%	1.00%	1.00%
Per Household Annual Property Transfer Tax Revenue	$11,345	$8,856	$3,790	$2,750

* The 1 % property tax rate is shared among cities, counties, special districts (including redevelopment), and schools.

Table 12-46: Total Per Household Revenue – Standard (Source: Strategic Economics, 2010.)

Item	SF Large Lot	SF Small Lot	SF Attached	Multifamily
Vehicle License Fee Revenue	$7.87	$7.87	$6.89	$5.88
Sales Tax Revenue	$199	$199	$199	$199
Property Transfer Tax Revenue	$28	$22	$17	$7
Property Tax Revenue	$3,618	$2,817	$3,100	$1,220
TOTAL	$3,853	$3,046	$3,323	$1,432

Table 12-47: Total Per Household Revenue - Compact-Greenfield (Source: Strategic Economics, 2010.)

Item	SF Large Lot	SF Small Lot	SF Attached	Multifamily
Vehicle License Fee Revenue	$7.87	$7.87	$6.89	$5.88
Sales Tax Revenue	$199	$199	$199	$199
Property Transfer Tax Revenue	$73	$57	$24	$17
Property Tax Revenue	$9,354	$7,302	$4,290	$3,050
TOTAL	$9,635	$7,567	$4,520	$3,272

Table 12-48: Total Per Household Revenue - Compact-Refill (Source: Strategic Economics, 2010.)

Item	SF Large Lot	SF Small Lot	SF Attached	Multifamily
Vehicle License Fee Revenue	$7.87	$7.87	$6.89	$5.88
Sales Tax Revenue	$199	$199	$199	$199
Property Transfer Tax Revenue	$86	$67	$22	$15
Property Tax Revenue	$10,937	$8,538	$4,010	$2,790
TOTAL	$11,231	$8,812	$4,238	$3,011

Table 12-49: Total Per Household Revenue – Urban (Source: Strategic Economics, 2010.)

Item	SF Large Lot	SF Small Lot	SF Attached	Multifamily
Vehicle License Fee Revenue	$7.87	$7.87	$6.89	$5.88
Sales Tax Revenue	$199	$199	$199	$199
Property Transfer Tax Revenue	$89	$70	$21	$15
Property Tax Revenue	$10,345	$8,856	$3,790	$2,750
TOTAL	$11,641	$9,133	$4,017	$2,970

Table 12-50: Total Per Acre Revenue, by Housing Type and LDC (Source: Strategic Economics, 2010.)

	Standard	Compact-Greenfield	Compact-Refill	Urban
Single Family Large-Lot	$13,036	$32,597	$37,996	$39,385
Single Family Small-Lot	$25,893	$64,312	$74,900	$77,624
Single Family Attached	$62,940	$85,602	$80,270	$76,080
Multi-Family	$57,278	$130,880	$120,423	$118,814

KEY FINDINGS

The key findings resulting from Strategic Economics' 2010 fiscal impacts analysis study are summarized below; this discussion may be helpful in interpreting the results of UrbanFootprint's fiscal impacts analysis module.

Benefits of Higher Intensity Development Patterns

Strategic Economics found that there are significant economic benefits to higher intensity development patterns in terms of infrastructure cost savings. Some cities, including San Diego and Santa Rosa, have calculated the marginal cost difference between infill and Greenfield locations for infrastructure capital costs, which demonstrates that infill development can provide significant savings to the cities. The analysis found that on a general basis, per unit and per acre infrastructure costs are significantly lower for compact refill and urban LDCs, compared to the standard LDC. There is a marginal increase in per unit and per acre infrastructure costs for compact greenfield communities compared to standard cities, partly due to the enhanced streetscape and urban design "placemaking" features often found in these types of developments (see Figure 12-3 and Figure 12-4).

Figure 12-3: Per Household Infrastructure Costs, by City Type

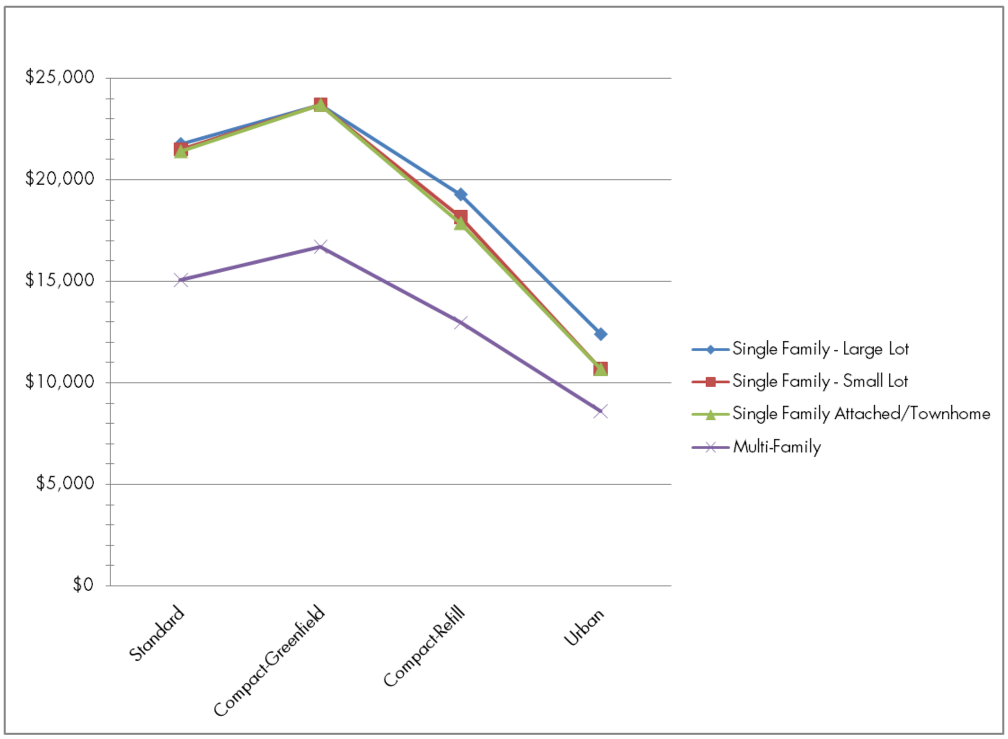
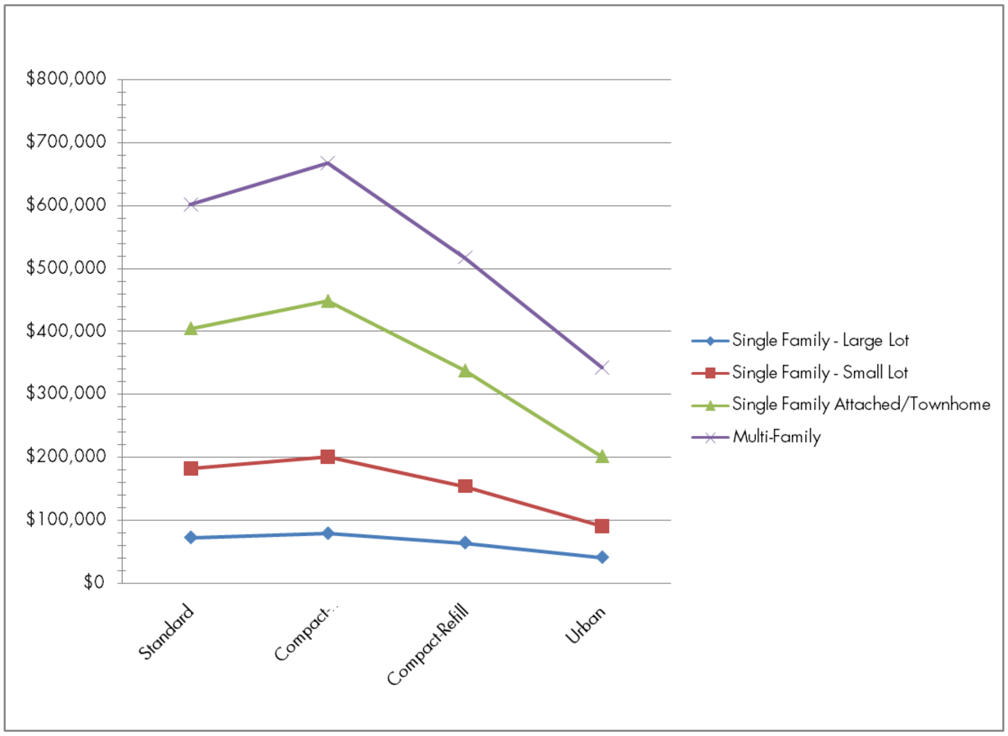


Figure 12-4: Per Acre Infrastructure Costs, by City Type



Economies of Scale for O&M

There are economies of scale for certain categories of O&M costs, such as engineering and public works (see Figure 12-5 and Figure 12-6). Engineering and public works O&M costs are reduced significantly for compact greenfield and compact refill cities, compared to standard cities. The lower cost of providing these types of services correlates to the efficiencies achieved from more compact physical development patterns, including lower linear feet of roads and sewer pipes, and the reduced capital costs discussed above. However, urban cities benefit less from these savings due to factors described in more detail below.

Figure 12-5: Per Household O&M Costs for Engineering and Public Works, by City Type

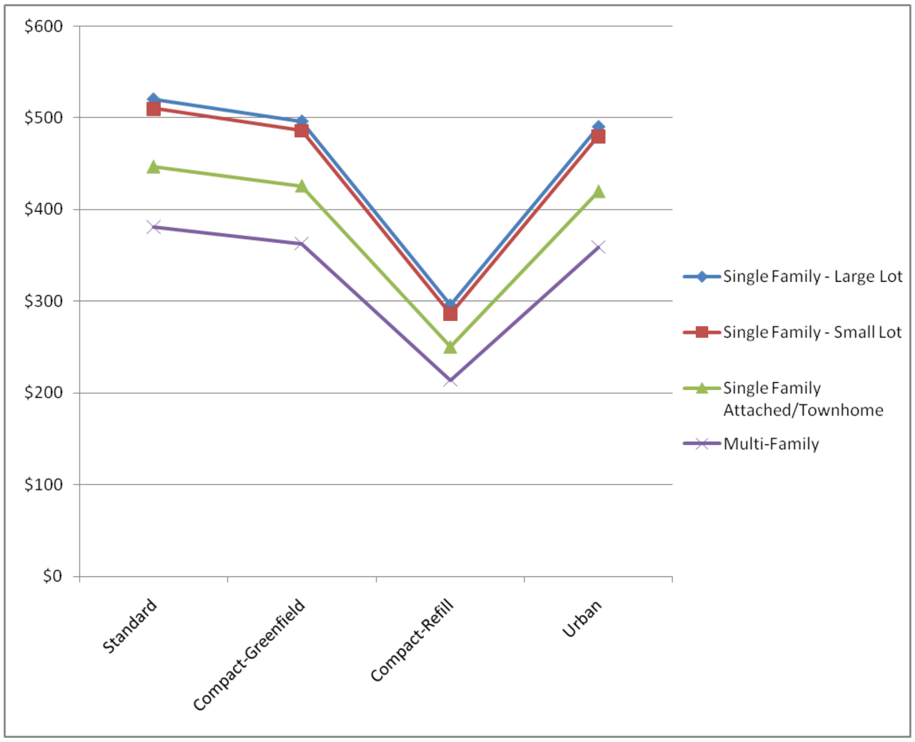
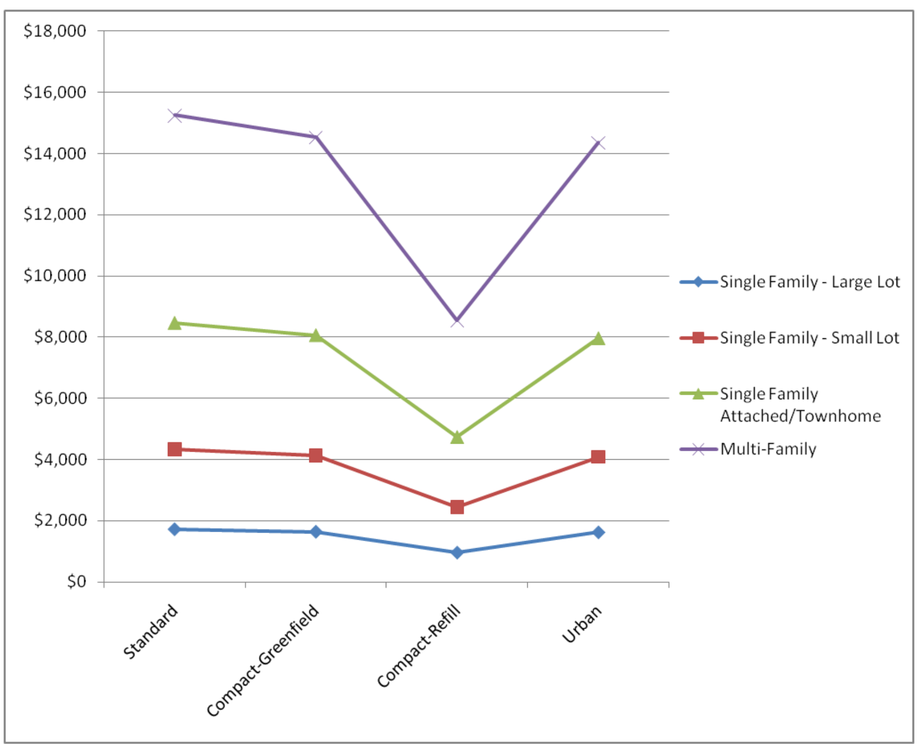


Figure 12-6: Per Acre O&M Costs for Engineering and Public Works, by City Type



Higher Costs of Compact Development for Certain Types of O&M Costs

Other categories of O&M costs, such as public safety and community services, generally increase with higher intensity land development patterns (see Figure 12-7 through Figure 12-10). This is somewhat attributable to variable economic conditions present in different cities. For example, urban places generally have a higher cost of living and average wage. Therefore, these cities often exhibit higher operating and maintenance costs per capita compared to compact and refill places. In addition, urban cities often provide a greater level of service than standard or refill cities (e.g., providing higher ratios of officers per capita, or a wider array of community programs).

Figure 12-7: Per Household O&M Costs for Public Safety, by City Type

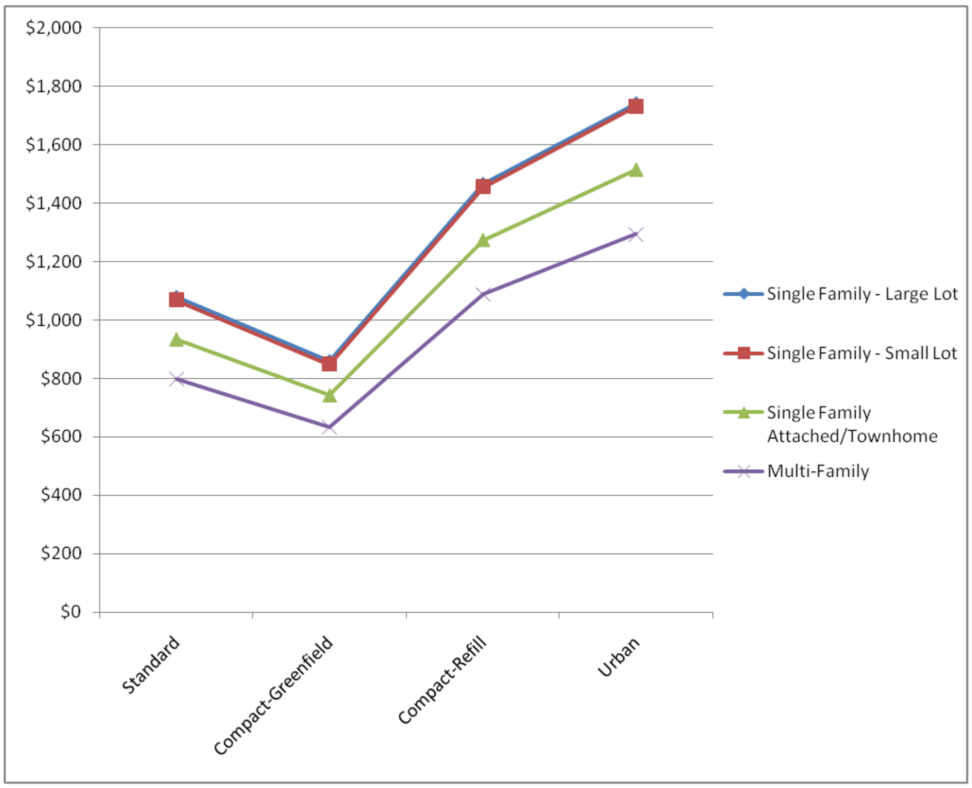


Figure 12-8: Per Acre O&M Costs for Public Safety, by City Type

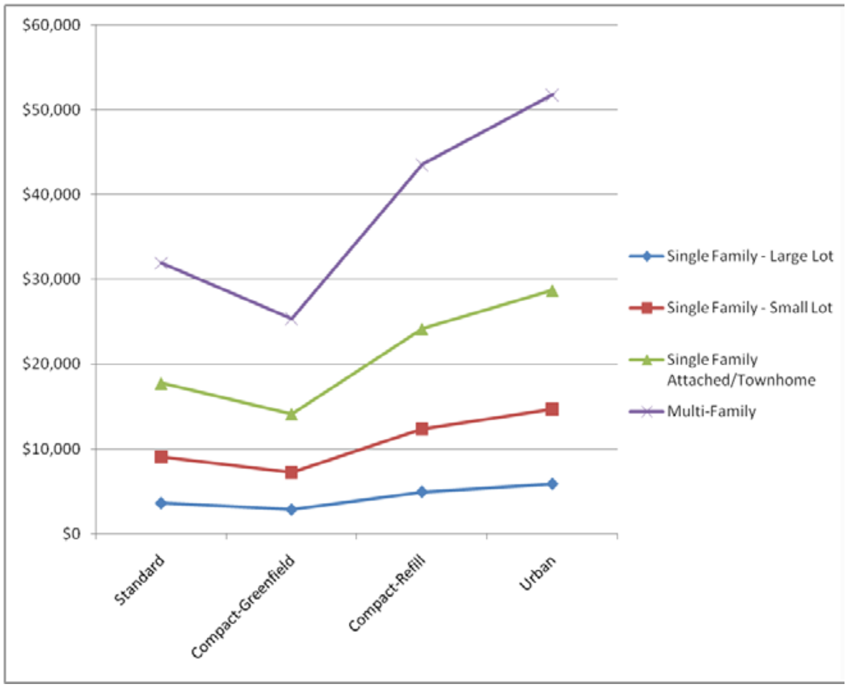


Figure 12-9: Per Household O&M Costs for Community Services, by City Type

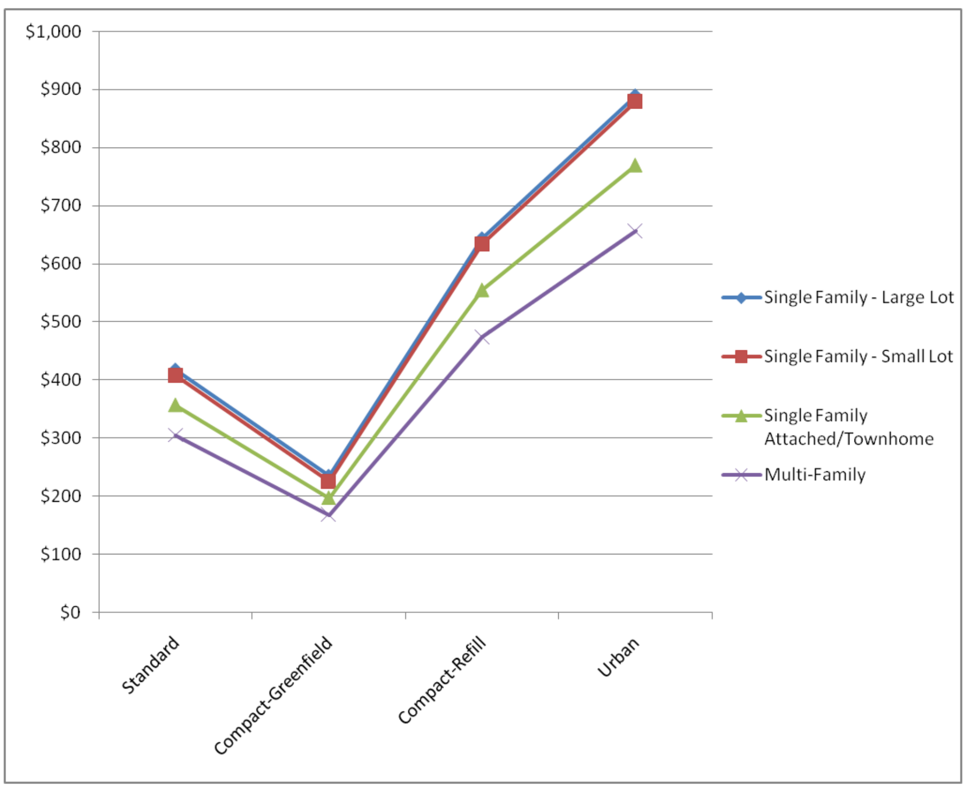
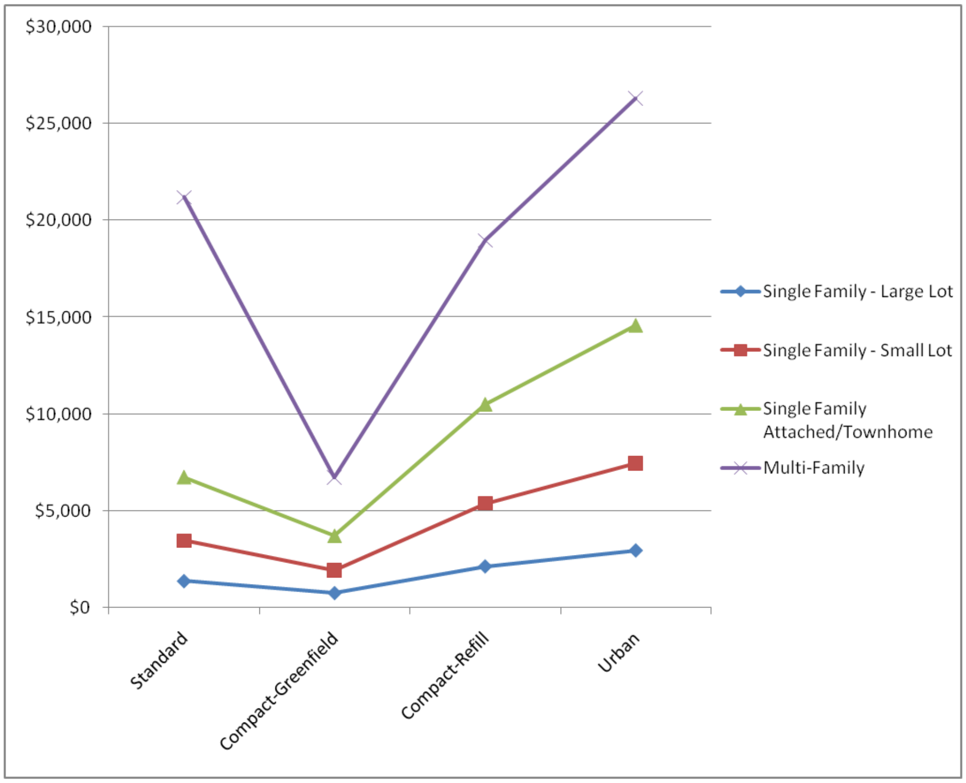


Figure 12-10: Per Acre O&M Costs for Community Services, by City Type



Compact and Urban Areas Generate More Revenue

The per acre and per unit revenues generated in compact greenfield, compact refill, and urban cities is significantly higher than in standard cities for all housing types (see Figure 12-11 and Figure 12-12). On average, housing in the standard cities demand lower market values compared to higher intensity locations. The price differential is most pronounced for single-family detached units.

Figure 12-11: Per Household Projected Revenue, by City Type

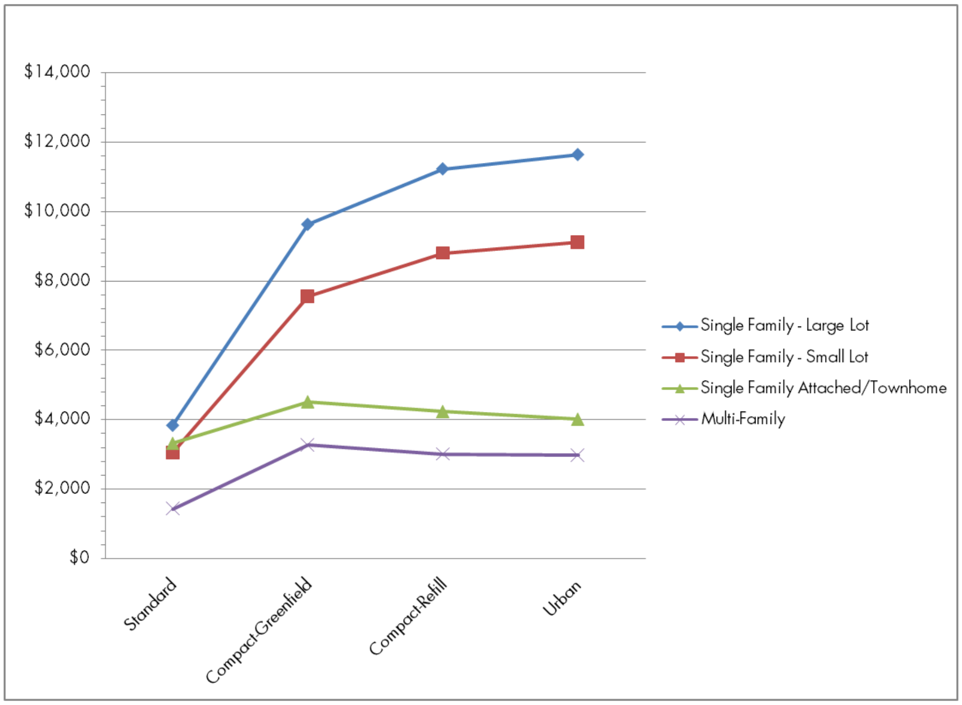
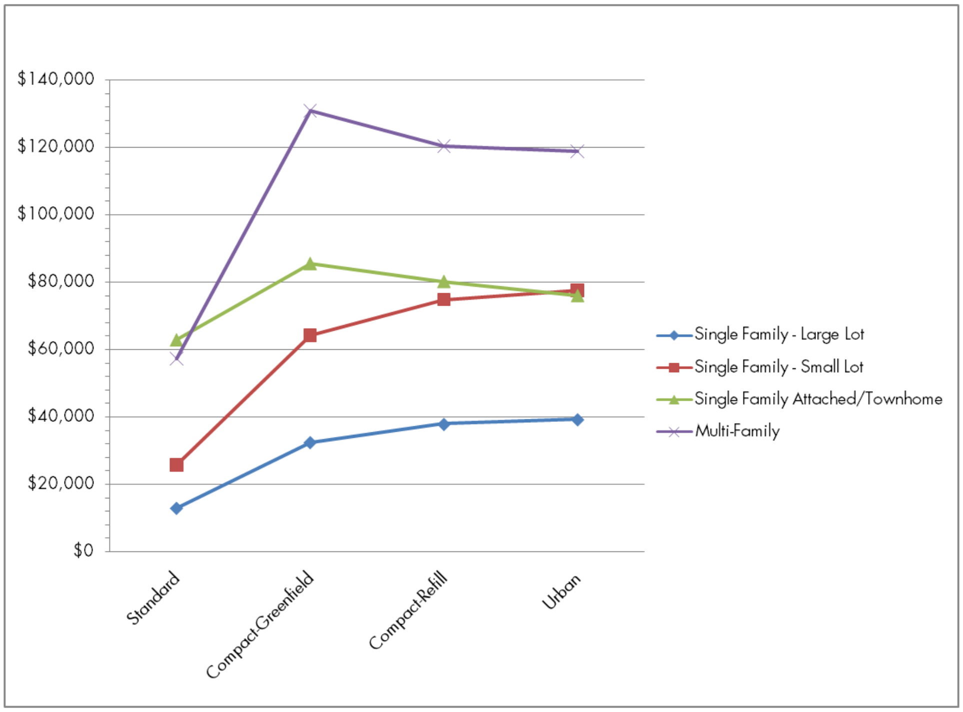


Figure 12-12: Per Acre Projected Revenue, by City Type



Fiscal Impacts Appendix II: Study for Southern California

This appendix provides the results of the municipal costs and revenue analysis performed for the Southern California Association of Government's (SCAG) 2012 RTP SCS process. SCAG hired Strategic Economics, as part of a consultant team led by Calthorpe Associates, to estimate the fiscal impacts to cities that result from varying land use scenarios in the SCAG region. Calthorpe Associates used the fiscal impact results developed by Strategic Economics, in conjunction with other inputs, to estimate the impacts of growth and infrastructure decisions on a variety of critical indicators for the six-county SCAG region.

This appendix summarizes the methodology and results of the fiscal impact analysis for the SCAG region. It is organized into four sections: Study Methodology; Base Assumptions; Results; and Key Findings.

STUDY METHODOLOGY

In order to measure the fiscal impacts of various land development patterns, Strategic Economics measured the municipal costs and revenues incurred from each individual household or dwelling unit. This methodology allows the comparison of different development patterns rather than land use plans associated with a specific place.

The analysis considered the following costs and revenues:

1) Capital costs of building new infrastructure and facilities
2) Operations and Maintenance (O&M) costs for facilities and provision of municipal services
3) Primary sources of local tax revenues (property taxes, property transfer taxes, sales taxes, and vehicle license fees).

Due to the fact that schools are not primarily funded directly by cities, the impact to school districts was not measured. Finally, because this fiscal analysis only measures the impact of households, Strategic Economics netted out all costs and revenues associated with employment uses and attributed only those costs and revenues associated with residential uses.

Infrastructure Costs

Infrastructure costs, or the capital costs of building public infrastructure and facilities to serve new development, are one-time costs. Strategic Economics estimated infrastructure costs based on development impact fees assessed in various cities. Development impact fees (DIFs) represent the capital costs to cities to provide the infrastructure needed to serve new development. In California these fees are typically calculated to capture the full costs of infrastructure investments triggered by new residential development. Cities may reduce fees for commercial development but are less likely to subsidize the infrastructure costs associated with residential development. Some cities have deferred or reduced impact fees during the recent economic downturn. Strategic Economics avoided using impact fee data for those cities. The infrastructure costs considered in this analysis include the following major categories:

- Streets and Transportation, or the costs of new roads required to serve development;
- Parks, or the costs of parks and recreation facilities required to serve development;
- Sewage/Wastewater, or the costs of wastewater treatment facilities required to serve development; and
- Water, or the costs of water treatment required to serve development.

The above categories cover the most commonly incurred infrastructure costs associated with new development. Some cities may charge development impact fees for other categories of infrastructure, including General Government, Police, Fire, and Libraries. Those categories are not charged consistently and typically make up a smaller portion of infrastructure costs associated with new development, and were therefore excluded from this analysis.

Operations and Maintenance Costs

Operations and maintenance costs (O&M) represent the cost of providing ongoing services to new development. Strategic Economics calculated selected O&M costs on a per capita basis using General Fund expenditures of the representative cities included in the analysis. O&M costs are broken out into the following major categories:

- General Government: including administrative and legislative functions.
- Public Safety: including fire and police services.
- Community Services: including library and recreation services.
- Engineering and Public Works: including only General Fund public works functions.

Community development and other categories often paid for using designated revenues (such as building permit fees) were excluded. Similarly, debt service costs and capital outlay from the General Fund were excluded from the analysis.

Revenues

Revenues are calculated on a per capita or household basis using regional or statewide averages for some revenue factors and regional property value calculations. The methodology for deriving revenue estimates is described in further detail in the Base Assumptions section of this appendix.

Example Cities and Land Development Categories

Strategic Economics worked with Calthorpe Associates to identify example cities to correspond with the Land Development Categories (LDCs). The LDCs as defined in the fiscal analysis are as follows:

- **Standard** is the least intense LDC and is represented by suburban and stand-alone cities that have lower densities and fewer nonresidential uses. Cities used in the Standard category include:
    - Anaheim;
    - Calexico;
    - Chino;
    - Claremont;
    - Colton;

    - Coachella;
    - El Centro;
    - El Segundo;
    - Fontana;
    - Huntington Beach;
    - Imperial;
    - Irvine;
    - La Quinta;
    - Lancaster;
    - Murrieta;
    - Newport Beach;
    - Oxnard;
    - Perris;
    - Rancho Cucamonga;
    - Redlands;
    - Rialto;
    - Riverside;
    - San Bernadino;
    - San Gabriel;
    - San Jacinto;
    - Santa Clarita;
    - Stanton; and
    - Yucaipa.
- **Compact – Greenfield** is less intense than Urban, but is a walkable development pattern with a mix of single-family small-lot, single-family attached/townhome and multi-family units in addition to a mix of nonresidential uses. LDC Cities used in the Compact - Greenfield category include:
    - Brea (District 2);
    - Costa Mesa;
    - Los Angeles (subdivision); and
    - San Buenaventura (Ventura).
- **Compact – Refill**, like the Compact – Greenfield LDC, is less intense than Urban, and is represented by largely built out cities with a mix of housing types and nonresidential uses. Cities used in the Compact - Refill category include:
    - Brea (District 1);
    - El Monte;
    - Fountain Valley;
    - Lomita;
    - Los Alamitos;
    - Los Angeles (infill area);
    - Manhattan Beach;
    - Pasadena;

- Signal Hill; and
- South Pasadena.

- **Urban** is the most intense and most mixed of the LDCs. Because there are very few places that fit the Urban classification, Strategic Economics included data from cities outside of the SCAG area. Cities analyzed in the Urban category include:
  - Emeryville;
  - Berkeley;
  - Long Beach;
  - San Diego (Centre City);
  - San Francisco; and
  - West Hollywood.

In addition to the differences in LDCs as described above, the results were found to have regional differences based on location, primarily due to home values. Strategic Economics therefore calculated revenues for two sub-regions within the SCAG region:

- Coastal sub-region: defined as Los Angeles, Orange, and Ventura counties; and
- Inland sub-region: defined as Imperial, Riverside, and San Bernardino counties.

Figure 12-13 on the following page maps the sub-regions and cities used by Strategic Economics to represent the LDCs in the fiscal analysis.

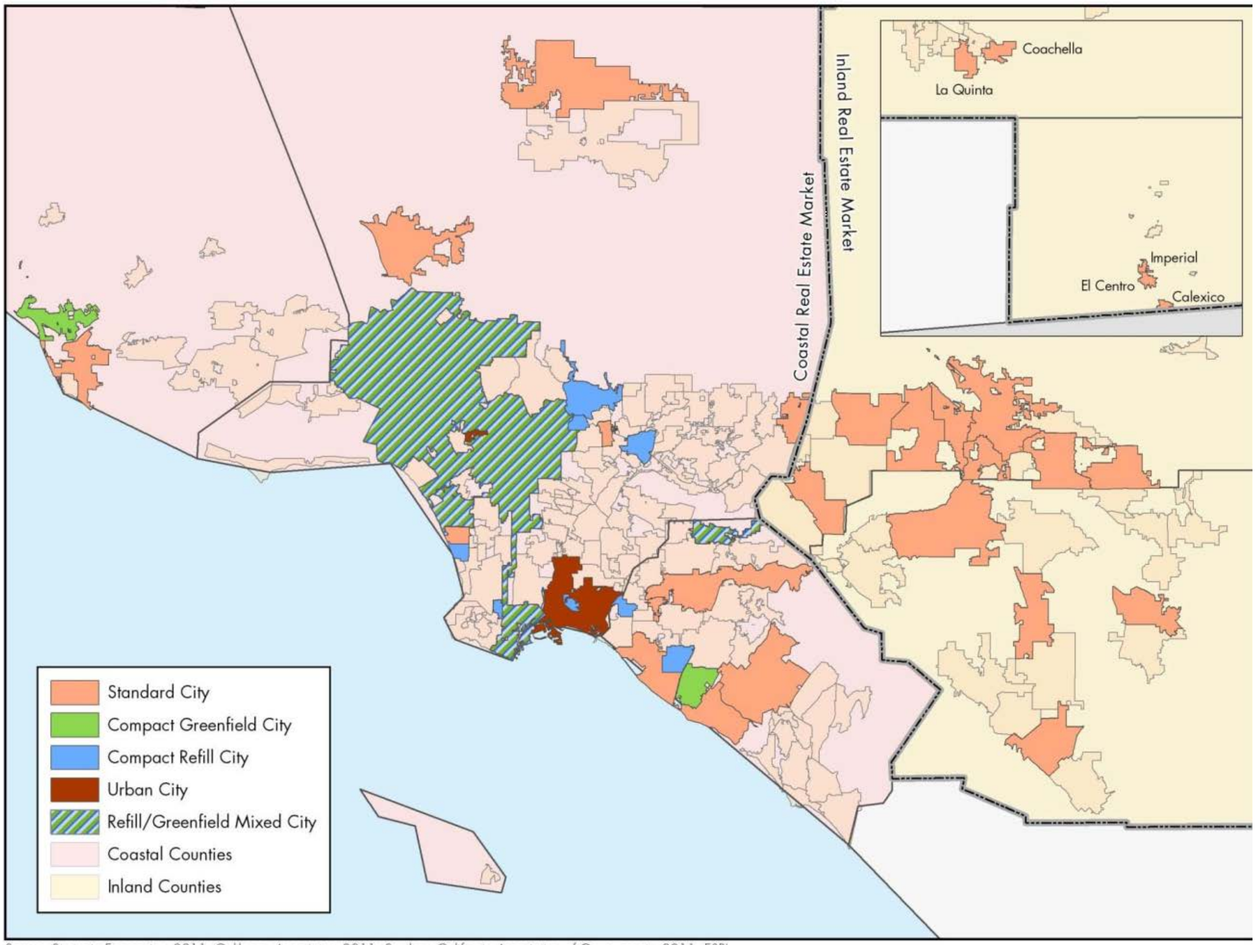
Limitations of data/methodology

This methodology allows the generalization of fiscal impacts across the SCAG region, but it has its limitations. This fiscal impact analysis is limited to the impacts associated with households and does not consider the impacts of nonresidential development. Also, the analysis only considers General Fund costs and revenues and does not measure the impacts of development on services or infrastructure that may be paid for from other funding sources.

This analysis does not consider other economic benefits often attributed to "smart growth," such as lower transportation costs for households and businesses, improved access to jobs or housing for low-income people, and enhanced economic productivity and innovation. Because this analysis is meant to compare the relative impacts of the LDCs and is not intended to determine the net fiscal impact of a land use alternative to a specific municipality, it does not consider every source of revenue and expenditure. Rather, the analysis focuses on the major categories of cost and revenue for cities.

Furthermore, due to the wide variability in the property tax revenue structure for cities in the SCAG region it was not possible to calculate the net fiscal impacts under each LDC.

Figure 12-13: SCAG Cities Representing Land Development Categories



Source: Strategic Economics, 2011; Calthorpe Associates, 2011; Southern California Association of Governments, 2011; ESRI.

BASE ASSUMPTIONS

As with all fiscal impact analyses, the assumptions drive the results. Strategic Economics created its assumptions based upon available data for population and housing characteristics, municipal revenue and cost factors, real estate market indicators, and commonly applied fiscal impact analysis standards.

Base Year

The fiscal analysis is based on the year 2008. When 2008 data was not available, assumptions were adjusted to 2008 dollars.

Land Use Assumptions

As described above, Strategic Economics developed a list of cities and places to represent the four LDCs used in this analysis. As part of the Vision California process, Strategic Economics and Calthorpe Associates developed a series of land use assumptions by LDC. Many of the same land use assumptions were used for the SCAG region analysis. The model calculates the fiscal impacts of four housing types:

- Single Family Small Lot Detached (SF Small Lot);
- Single Family Large Lot Detached (SF Large Lot);

- Single Family Attached/Townhome (Townhome); and
- Multi-Family.

Table 12-51 shows the assumptions for average unit size (in square feet) for the four housing types.

Table 12-51: Average Unit Size (Square Feet), by Housing Type

Housing Type	Average Unit Size (Square Feet)	Source
SF Small Lot Detached	1,700	US Census SOC 2009 Microdata
SF Large Lot Detached	3,100	US Census SOC 2009 Microdata
SF Attached/Townhome	1,650	US Census SOC 2009 Microdata
Multi-Family	1,150	US Census SOC 2009 Microdata

Table 12-52 shows the assumptions for average unit lot size for the four housing types.

Table 12-52: Per Unit Average Lot Size (Square Feet), by Housing Type

Housing Type	Gross Lot Size per Unit (Square Feet)	Source
SF Small Lot Detached	5,125	US Census SOC 2009 Microdata
SF Large Lot Detached	12,875	US Census SOC 2009 Microdata
SF Attached/Townhome	2,300	US Census SOC 2009 Microdata
Multi-Family	1,089	Calthorpe Associates/Strategic Economics

Based on the lot sizes described above, Strategic Economics made assumptions on average dwelling units per acre by housing type as shown in Table 12-53.

Table 12-53: Average Density Assumptions by Housing Type

Housing Type	Dwelling Units per Acre	Source
SF Small Lot Detached	8.5	US Census SOC 2009 Microdata
SF Large Lot Detached	3.4	US Census SOC 2009 Microdata
SF Attached/Townhome	18.9	US Census SOC 2009 Microdata
Multi-Family	40.0	Calthorpe Associates/Strategic Economics

Property Values

To calculate property values, Strategic Economics used housing market data for the SCAG region, including median housing values for the example cities from DataQuick, regional new home values from CBIA/Hanley Woods, rental market data from RealFacts and Marcus Millichap, and county- level new home values from the Real Estate Research Council of Southern California. Strategic Economics synthesized the regional housing data to calculate average new home values for the housing types for the two sub-regions determined to represent the LDCs. The following sets of tables show the average housing values by type for each of the LDCs in each of the sub-regions considered in the analysis.

After synthesizing the housing market data on a regional scale, Strategic Economics distinguished important sub-regional trends in the Southern California residential market. Coastal markets – defined as Los Angeles, Orange and Ventura Counties – demonstrated markedly higher sales values across product types when compared to the Inland SCAG region. The Inland market – defined as Riverside, San Bernadino and Imperial Counties – has lower sales prices and a less diverse mix of single family detached housing stock. Two separate revenue models were developed to better reflect these sub- regional trends. Using CBIA/Hanley Woods county-wide data on new home sales, Strategic Economics used a weighted average of home sales and median sales prices to develop inputs for the per square foot cost of new homes in the Coastal and Inland sub-regions.

Table 12-54 through Table 12-57 show average new home values for the Coastal sub-region.

Table 12-54: Coastal Sub-region Average Housing Values by Type - Standard

Housing Type	Value	Source
SF Small Lot Detached	$390,000	DQ News/CBIA/Hanley-Woods Reports
SF Large Lot Detached	$501,000	DQ News/CBIA/Hanley-Woods Reports
SF Attached/Townhome – For Sale	$360,000	DQ News/CBIA/Hanley-Woods Reports
Multi-Family – For Sale	$415,000	DQ News/CBIA/Hanley-Woods Reports
SF Attached/Townhome – Rental	$256,000	Real Facts/Marcus Millichap
Multi-Family - Rental	$189,000	Real Facts/Marcus Millichap

Table 12-55: Coastal Sub-region Average Housing Values by Type – Compact-Greenfield

Housing Type	Value	Source
SF Small Lot Detached	$508,000	DQ News/CBIA/Hanley-Woods Reports
SF Large Lot Detached	$652,000	DQ News/CBIA/Hanley-Woods Reports
SF Attached/Townhome – For Sale	$469,000	DQ News/CBIA/Hanley-Woods Reports
Multi-Family – For Sale	$541,000	DQ News/CBIA/Hanley-Woods Reports
SF Attached/Townhome – Rental	$333,000	Real Facts/Marcus Millichap
Multi-Family - Rental	$246,000	Real Facts/Marcus Millichap

Table 12-56: Coastal Sub-region Average Housing Values by Type – Compact-Refill

Housing Type	Value	Source
SF Small Lot Detached	$594,000	DQ News/CBIA/Hanley-Woods Reports
SF Large Lot Detached	$763,000	DQ News/CBIA/Hanley-Woods Reports
SF Attached/Townhome – For Sale	$548,000	DQ News/CBIA/Hanley-Woods Reports
Multi-Family – For Sale	$633,000	DQ News/CBIA/Hanley-Woods Reports
SF Attached/Townhome – Rental	$389,000	Real Facts/Marcus Millichap
Multi-Family - Rental	$288,000	Real Facts/Marcus Millichap

Table 12-57: Coastal Sub-region Average Housing Values by Type - Urban

Housing Type	Value	Source
SF Small Lot Detached	$549,000	DQ News/CBIA/Hanley-Woods Reports

SF Large Lot Detached	$705,000	DQ News/CBIA/Hanley-Woods Reports
SF Attached/Townhome – For Sale	$506,000	DQ News/CBIA/Hanley-Woods Reports
Multi-Family – For Sale	$585,000	DQ News/CBIA/Hanley-Woods Reports
SF Attached/Townhome – Rental	$360,000	Real Facts/Marcus Millichap
Multi-Family - Rental	$266,000	Real Facts/Marcus Millichap

Table 12-58 through Table 12-61 show average new home values for the Inland sub-region.

Table 12-58: Inland Sub-region Average Housing Values by Type - Standard

Housing Type	Value	Source
SF Small Lot Detached	$237,000	DQ News/CBIA/Hanley-Woods Reports
SF Large Lot Detached	$305,000	DQ News/CBIA/Hanley-Woods Reports
SF Attached/Townhome – For Sale	$253,000	DQ News/CBIA/Hanley-Woods Reports
Multi-Family – For Sale	$238,000	DQ News/CBIA/Hanley-Woods Reports
SF Attached/Townhome – Rental	$200,000	Real Facts/Marcus Millichap
Multi-Family - Rental	$139,000	Real Facts/Marcus Millichap

Table 12-59: Inland Sub-region Average Housing Values by Type – Compact-Greenfield

Housing Type	Value	Source
SF Small Lot Detached	$309,000	DQ News/CBIA/Hanley-Woods Reports
SF Large Lot Detached	$397,000	DQ News/CBIA/Hanley-Woods Reports
SF Attached/Townhome – For Sale	$329,000	DQ News/CBIA/Hanley-Woods Reports
Multi-Family – For Sale	$310,000	DQ News/CBIA/Hanley-Woods Reports
SF Attached/Townhome – Rental	$261,000	Real Facts/Marcus Millichap
Multi-Family - Rental	$181,000	Real Facts/Marcus Millichap

Table 12-60: Inland Sub-region Average Housing Values by Type – Compact-Refill

Housing Type	Value	Source
SF Small Lot Detached	$362,000	DQ News/CBIA/Hanley-Woods Reports
SF Large Lot Detached	$464,000	DQ News/CBIA/Hanley-Woods Reports
SF Attached/Townhome – For Sale	$385,000	DQ News/CBIA/Hanley-Woods Reports
Multi-Family – For Sale	$363,000	DQ News/CBIA/Hanley-Woods Reports
SF Attached/Townhome – Rental	$305,000	Real Facts/Marcus Millichap
Multi-Family - Rental	$212,000	Real Facts/Marcus Millichap

Table 12-61: Inland Sub-region Average Housing Values by Type - Urban

Housing Type	Value	Source
SF Small Lot Detached	$334,000	DQ News/CBIA/Hanley-Woods Reports
SF Large Lot Detached	$429,000	DQ News/CBIA/Hanley-Woods Reports
SF Attached/Townhome – For Sale	$356,000	DQ News/CBIA/Hanley-Woods Reports

Multi-Family – For Sale	$335,000	DQ News/CBIA/Hanley-Woods Reports
SF Attached/Townhome – Rental	$281,000	Real Facts/Marcus Millichap
Multi-Family - Rental	$195,000	Real Facts/Marcus Millichap

In order to calculate a blended value representing both for sale and rental units for the Townhome and Multi-family housing types, Strategic Economics used data on the percentage of new units built in California as for sale units versus rental units. The property value for those housing types was then derived from a weighted average of the values of for sale and rental units.

Household Assumptions

Strategic Economics gathered data on population, employment and household size and composition in order to make a series of assumptions on the service base. The service base is the population served by a municipality. Because this analysis does not consider the impacts of employees, Strategic Economics netted out costs and revenues associated with employment uses and attributed only those costs and revenues associated with residential uses to the housing types described above.[89]

Many of the costs and revenues in the fiscal analysis were calculated based on the net increase in population resulting from the household types included in the Rapid Fire development mix. To do that, the analysis uses averages for costs and revenues on a per capita basis. In some cases, the per capita cost and revenue factors are then applied to the population assumptions associated with a specific housing type to develop a per household calculation. For these calculations Strategic Economics collected data from the US Census Public-Use Microdata Samples (PUMS) 2009 files on persons per household by housing type as shown in Table 12-62.

Table 12-62: Average Household Size, by Housing Type

Housing Type	Average HH Size	Source
Single Family Detached	2.97	US Census Public-Use Microdata Samples (PUMS) 2009
SF Attached/Townhome	2.60	US Census Public-Use Microdata Samples (PUMS) 2009
Multi-Family	2.22	US Census Public-Use Microdata Samples (PUMS) 2009

Infrastructure Costs

This section summarizes the results for the infrastructure cost analysis. Table 12-63 shows how many example impact fees were considered in calculating the infrastructure costs by LDC.

Table 12-63: Number of Entries by Fee Type, by LDC (Source: Strategic Economics, 2011)

Infrastructure Category	Standard	Compact-Greenfield	Compact-Refill	Urban
Streets and Transportation	22	3	5	4
Parks	25	4	5	3
Sewage/Wastewater	15	4	6	5
Water	6	4	5	3

[89] To determine O&M costs associated with residential uses only Strategic Economics applied a "Service Population Factor" to costs. The residential service population was assumed to have a 1.0 factor, while the employment service population was assumed to have a 0.3 factor. The costs attributed to employment uses were then subtracted from total costs and revenues.

Table 12-64 through Table 12-67 show the average impact fees for selected infrastructure categories by LDC.

Table 12-64: Single Family Large Lot Average Impact Fees, by LDC (Source: Strategic Economics, 2011)

Infrastructure Category	Standard	Compact-Greenfield	Compact-Refill	Urban
Streets and Transportation	$4,565	$3,440	$845	$908
Parks	$4,806	$6,751	$9,422	$4,638
Sewage/Wastewater	$4,773	$3,611	$2,037	$2,312
Water	$4,764	$2,549	$2,659	$2,491
Total	$18,908	$16,352	$14,964	$10,350

Table 12-65: Single Family Small Lot Average Impact Fees, by LDC (Source: Strategic Economics, 2011)

Infrastructure Category	Standard	Compact-Greenfield	Compact-Refill	Urban
Streets and Transportation	$4,412	$3,323	$880	$908
Parks	$4,806	$6,751	$9,422	$4,638
Sewage/Wastewater	$4,483	$3,371	$1,589	$2,312
Water	$4,462	$2,549	$2,399	$2,491
Total	$18,162	$15,995	$14,291	$10,350

Table 12-66: Single Family Attached Average Impact Fees, by LDC (Source: Strategic Economics, 2011)

Infrastructure Category	Standard	Compact-Greenfield	Compact-Refill	Urban
Streets and Transportation	$4,259	$3,207	$880	$908
Parks	$4,672	$6,751	$8,837	$4,638
Sewage/Wastewater	$4,287	$3,371	$1,737	$2,312
Water	$4,193	$2,549	$2,399	$2,491
Total	$17,411	$15,879	$13,853	$10,350

Table 12-67: Multi-Family Average Impact Fees, by LDC (Source: Strategic Economics, 2011)

Infrastructure Category	Standard	Compact-Greenfield	Compact-Refill	Urban
Streets and Transportation	$3,639	$2,055	$865	$783
Parks	$3,978	$5,769	$6,589	$3,605
Sewage/Wastewater	$3,621	$2,878	$1,314	$1,581
Water	$3,785	$2,445	$2,339	$2,224
Total	$15,022	$13,148	$11,107	$8,192

Table 12-68 sums the infrastructure costs as represented by the impact fees on a per-housing unit by housing type and LDC.

Table 12-68: Per Housing Unit Impact Fees, by Housing Type and LDC (Source: Strategic Economics, 2011)

	Standard	Compact-Greenfield	Compact-Refill	Urban
Single Family Large-Lot	$18,908	$16,352	$14,964	$10,350
Single Family Small-Lot	$18,162	$15,995	$14,291	$10,350
Single Family Attached	$17,411	$15,879	$13,853	$10,350

Multi-Family	$15,022	$13,148	$11,107	$8,192

Table 12-69 sums the infrastructure costs as represented by the impact fees on a per acre basis by housing type and LDC.

Table 12-69: Per Acre Impact Fees, by Housing Type and LDC (Source: Strategic Economics, 2011)

	Standard	Compact-Greenfield	Compact-Refill	Urban
Single Family Large-Lot	$63,909	$55,268	$50,577	$34,982
Single Family Small-Lot	$154,376	$135,961	$121,470	$87,972
Single Family Attached	$329,758	$300,732	$262,372	$196,013
Multi-Family	$600,877	$525,927	$444,270	$327,676

Figure 12-14 and Figure 12-15 show the per-household and per-acre infrastructure costs as represented by the impact fees by housing type and LDC, respectively.

Figure 12-14: Per Household Infrastructure Costs, by LDC and Housing Type (Source: Strategic Economics, 2011.)

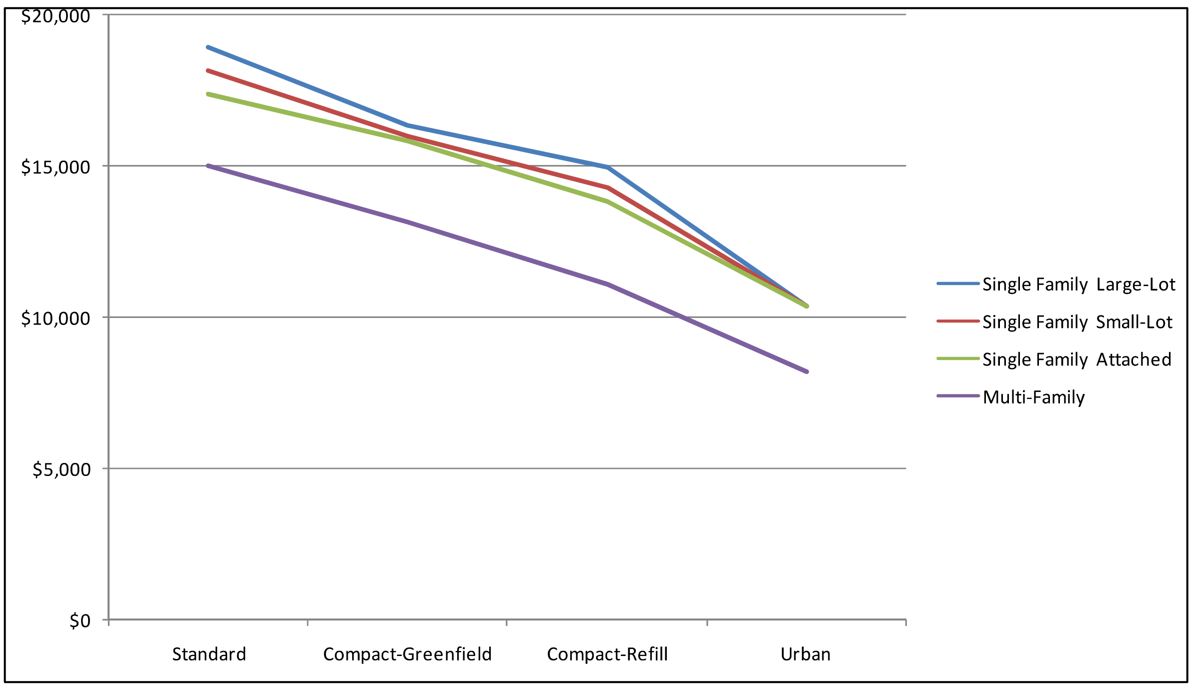
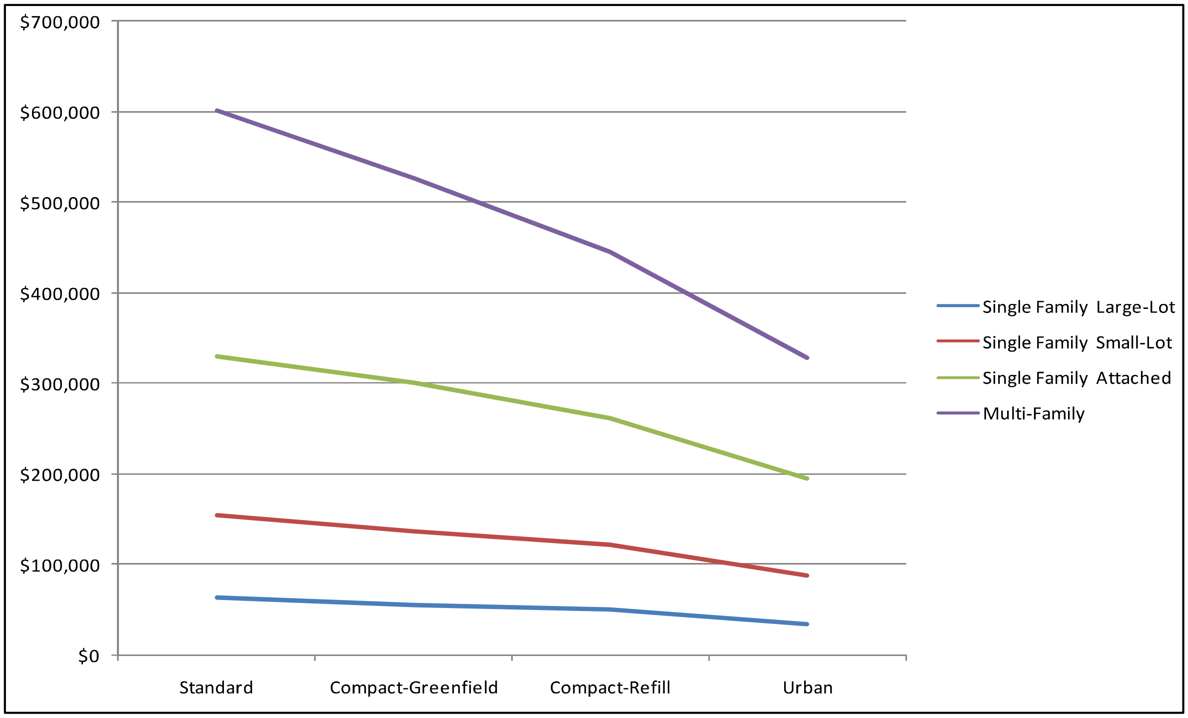


Figure 1H-15: Per Acre Infrastructure Costs, by LDC and Housing Type (Source: Strategic Economics, 2011.)



Operations and Maintenance Costs

This section summarizes the results for the operations and maintenance cost analysis. Table 12-70 through Table 12-72 show the average operations and maintenance costs per household for selected categories by LDC.

Table 1H-70: Single Family Detached Per Household Operations and Maintenance Costs, by LDC (Source: Strategic Economics, 2011)

	Standard	Compact-Greenfield	Compact-Refill	Urban
General Government	$379	$390	$385	$510
Public Safety	$1,150	$1,259	$1,130	$1,091
Community Services	$258	$211	$239	$508
Engineering and Public Works	$249	$223	$213	$220
Total	$2,036	$2,083	$1,967	$2,328

Table 1H-71: Single Family Attached Per Household Operations and Maintenance Costs, by LDC (Source: Strategic Economics, 2011)

	Standard	Compact-Greenfield	Compact-Refill	Urban
General Government	$332	$341	$337	$447
Public Safety	$1,007	$1,102	$989	$955
Community Services	$226	$185	$209	$444
Engineering and Public Works	$218	$196	$187	$192
Total	$1,782	$1,824	$1,722	$2,038

Table 12-72: Multi-Family Per Household Operations and Maintenance Costs, by LDC (Source: Strategic Economics, 2011)

	Standard	Compact-Greenfield	Compact-Refill	Urban
General Government	$283	$291	$288	$381
Public Safety	$860	$941	$844	$816
Community Services	$193	$158	$179	$379
Engineering and Public Works	$186	$167	$160	$164
Total	$1,522	$1,557	$1,471	$1,740

Table 12-73 through Table 12-76 show the average operations and maintenance costs per acre for selected categories by LDC.

Table 12-73: Single Family Large-Lot Per Acre Operations and Maintenance Costs, by LDC (Source: Strategic Economics, 2011)

	Standard	Compact-Greenfield	Compact-Refill	Urban
General Government	$1,281	$1,317	$1,302	$1,724
Public Safety	$3,888	$4,255	$3,818	$3,688
Community Services	$873	$714	$808	$1,716
Engineering and Public Works	$840	$755	$721	$742
Total	$6,882	$7,042	$6,650	$7,870

Table 12-74: Single Family Small-Lot Per Acre Operations and Maintenance Costs, by LDC (Source: Strategic Economics, 2011)

	Standard	Compact-Greenfield	Compact-Refill	Urban
General Government	$3,220	$3,312	$3,275	$4,335
Public Safety	$9,778	$10,702	$9,602	$9,274
Community Services	$2,195	$1,795	$2,033	$4,315
Engineering and Public Works	$2,114	$1,900	$1,814	$1,866
Total	$17,307	$17,708	$16,723	$19,791

Table 12-75: Single Family Attached Per Acre Operations and Maintenance Costs, by LDC (Source: Strategic Economics, 2011)

	Standard	Compact-Greenfield	Compact-Refill	Urban
General Government	$6,281	$6,461	$6,387	$8,456
Public Safety	$19,072	$20,874	$18,729	$18,090
Community Services	$4,281	$3,500	$3,966	$8,416
Engineering and Public Works	$4,123	$3,706	$3,539	$3,640
Total	$33,758	$34,541	$32,620	$38,603

Table 12-76: Multi-Family Per Acre Operations and Maintenance Costs, by LDC (Source: Strategic Economics, 2011)

	Standard	Compact-Greenfield	Compact-Refill	Urban
General Government	$11,328	$11,652	$11,518	$15,250
Public Safety	$34,394	$37,643	$33,774	$32,623
Community Services	$7,720	$6,312	$7,152	$15,178
Engineering and Public Works	$7,435	$6,682	$6,381	$6,564
Total	$60,877	$62,290	$58,825	$69,614

Figure 12-16 through Figure 12-19 show the per acre O&M costs for general government, public safety, community services, and engineering and public works by housing type and LDC, respectively.

Figure 12-16: Per Acre General Government O&M Costs, by LDC and Housing Type (Source: Strategic Economics, 2011)

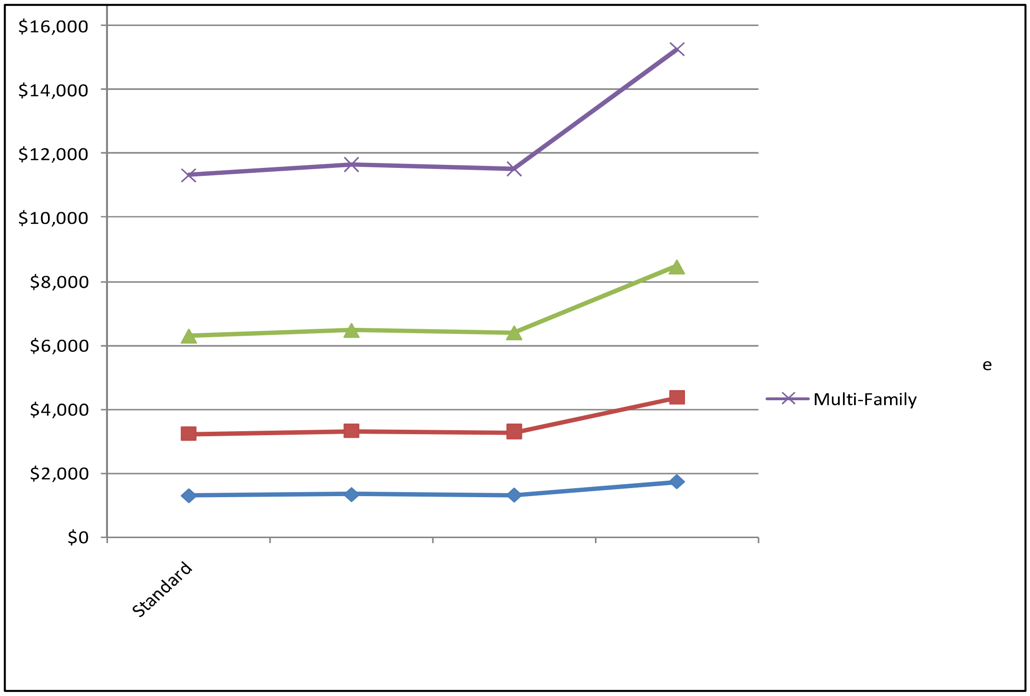


Figure 12-17: Per Acre Public Safety O&M Costs, by LDC and Housing Type (Source: Strategic Economics, 2011)

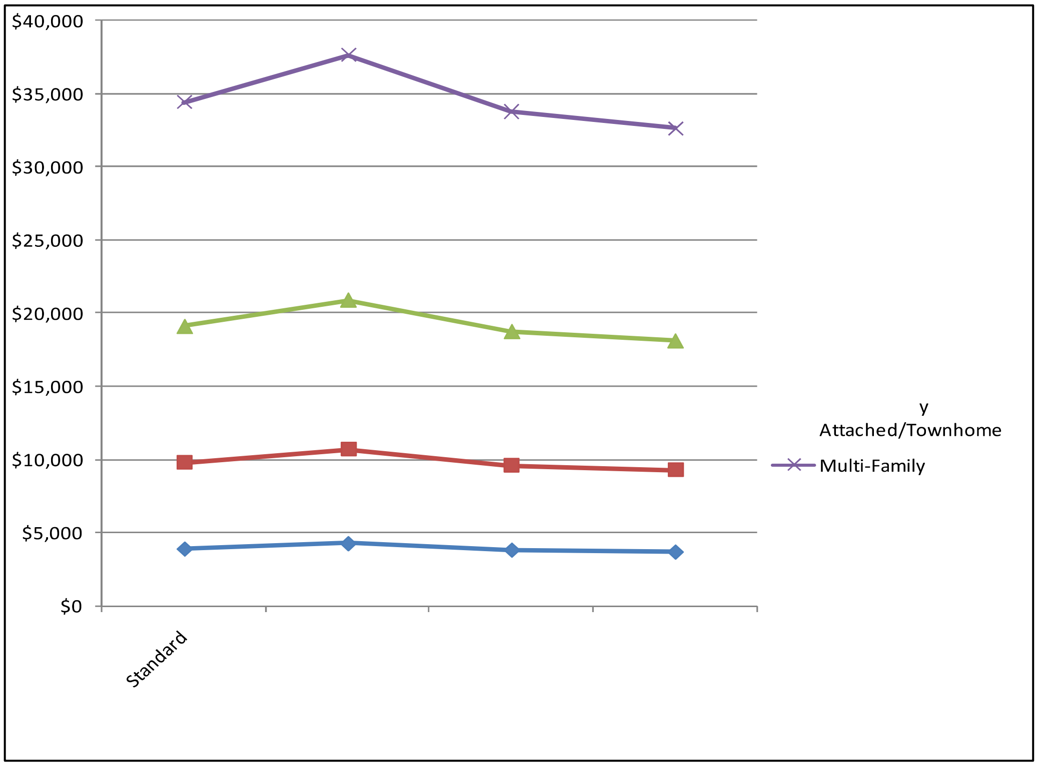


Figure 12-18: Per Acre Community Services O&M Costs, by LDC (Source: Strategic Economics, 2011)

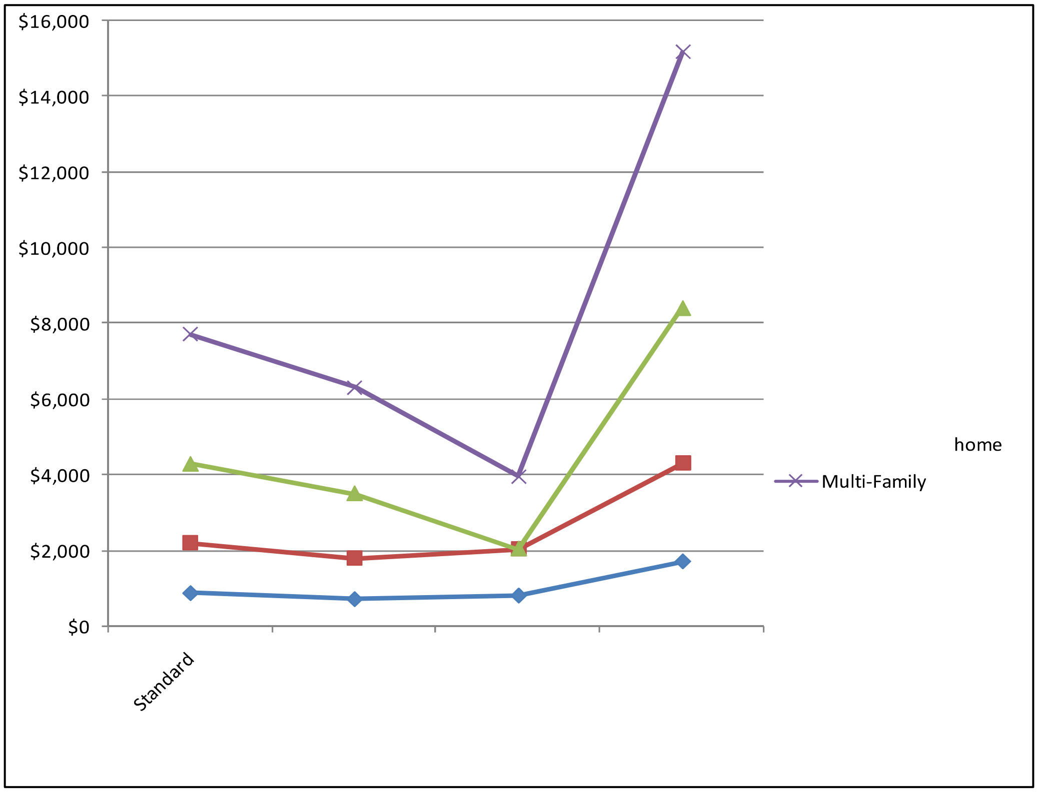
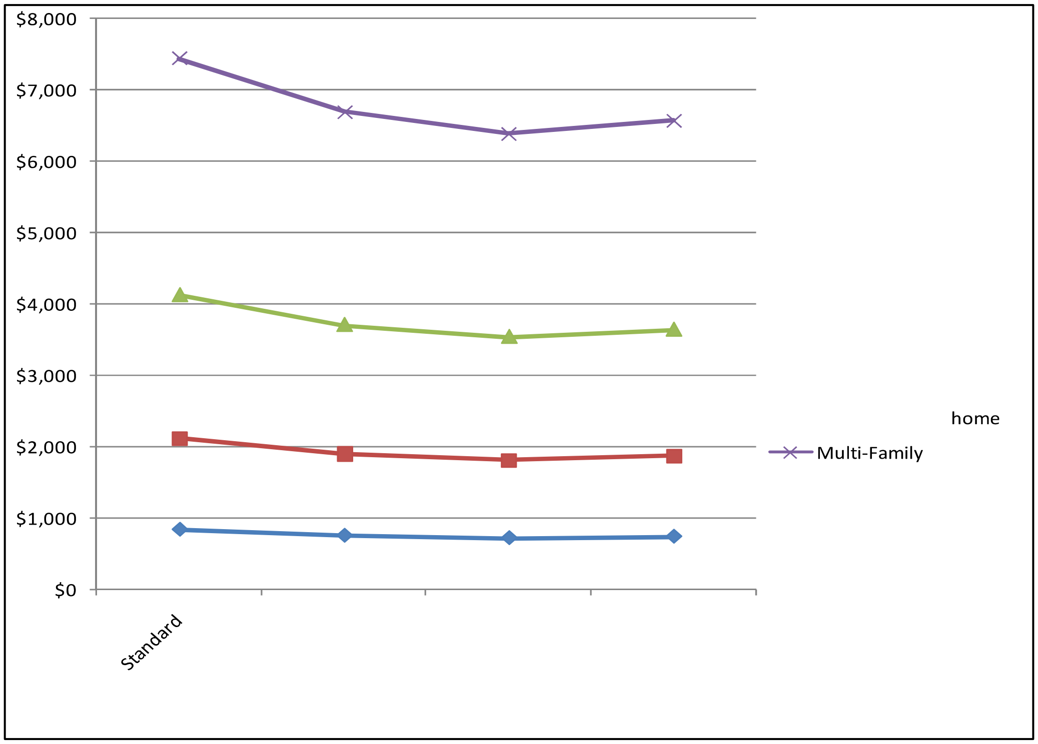


Figure 12-19: Per Acre Engineering and Public Works O&M Costs, by LDC (Source: Strategic Economics, 2011)



Revenues

This section summarizes the results for the revenue analysis. Table 12-77 through Table 12-80 show the estimated revenues per household by LDC for the Coastal sub-region.

Table 12-77: Coastal Sub-Region Per Household Revenue – Standard (Source: Strategic Economics, 2011)

Item	SF Large Lot	SF Small Lot	SF Attached	Multifamily
Vehicle License Fee Revenue	$8.23	$8.23	$8.23	$8.23
Sales Tax Revenue	$222	$222	$222	$222
Property Transfer Tax Revenue	$39	$31	$18	$13
Property Tax Revenue	$5,010	$3,900	$3,320	$2,330
Total	$5,279	$4,160	$3,568	$2,573

Table 12-78: Coastal Sub-Region Per Household Revenue - Compact-Greenfield (Source: Strategic Economics, 2011)

Item	SF Large Lot	SF Small Lot	SF Attached	Multifamily
Vehicle License Fee Revenue	$8.23	$8.23	$8.23	$8.23
Sales Tax Revenue	$222	$222	$222	$222
Property Transfer Tax Revenue	$51	$40	$24	$17
Property Tax Revenue	$6,520	$5,080	$4,330	$3,030
Total	$6,801	$5,350	$4,584	$3,276

Table 12-79: Coastal Sub-Region Per Household Revenue - Compact-Refill (Source: Strategic Economics, 2011)

Item	SF Large Lot	SF Small Lot	SF Attached	Multifamily
Vehicle License Fee Revenue	$8.23	$8.23	$8.23	$8.23
Sales Tax Revenue	$222	$222	$222	$222
Property Transfer Tax Revenue	$60	$47	$28	$20
Property Tax Revenue	$7,630	$5,940	$5,050	$3,550
Total	$7,920	$6,216	$5,308	$3,799

Table 12-80: Coastal Sub-Region Per Household Revenue – Urban (Source: Strategic Economics, 2011)

Item	SF Large Lot	SF Small Lot	SF Attached	Multifamily
Vehicle License Fee Revenue	$8.23	$8.23	$8.23	$8.23
Sales Tax Revenue	$222	$222	$222	$222
Property Transfer Tax Revenue	$55	$43	$26	$18
Property Tax Revenue	$7,050	$5,490	$4,670	$3,280
Total	$7,335	$5,763	$4,925	$3,528

Table 12-81 shows the estimated revenues per acre by housing type and LDC for the Coastal sub-region.

Table 12-81: Coastal Sub-Region Per Acre Revenue, by Housing Type and LDC (Source: Strategic Economics, 2011)

	Standard	Compact-Greenfield	Compact-Refill	Urban
Single Family Large-Lot	$17,861	$23,010	$26,795	$24,817
Single Family Small-Lot	$35,362	$45,470	$52,837	$48,982
Single Family Attached	$67,576	$86,810	$100,521	$93,285
Multi-Family	$102,905	$131,059	$151,973	$141,114

Table 12-82 through Table 12-85 show the estimated revenues per household by LDC for the Inland sub-region.

Table 12-82: Inland Sub-Region Per Household Revenue – Standard (Source: Strategic Economics, 2011)

Item	SF Large Lot	SF Small Lot	SF Attached	Multifamily
Vehicle License Fee Revenue	$8.23	$8.23	$8.23	$8.23
Sales Tax Revenue	$222	$222	$222	$222
Property Transfer Tax Revenue	$24	$19	$13	$9
Property Tax Revenue	$3,050	$2,370	$2,390	$1,580
Total	$3,304	$2,618	$2,633	$1,818

Table 12-83: Inland Sub-Region Per Household Revenue - Compact-Greenfield (Source: Strategic Economics, 2011)

Item	SF Large Lot	SF Small Lot	SF Attached	Multifamily
Vehicle License Fee Revenue	$8.23	$8.23	$8.23	$8.23
Sales Tax Revenue	$222	$222	$222	$222
Property Transfer Tax Revenue	$31	$24	$17	$11
Property Tax Revenue	$3,970	$3,090	$3,110	$2,060
Total	$4,231	$3,344	$3,357	$2,301

Table 12-84: Inland Sub-Region Per Household Revenue - Compact-Refill (Source: Strategic Economics, 2011)

Item	SF Large Lot	SF Small Lot	SF Attached	Multifamily
Vehicle License Fee Revenue	$8.23	$8.23	$8.23	$8.23
Sales Tax Revenue	$222	$222	$222	$222
Property Transfer Tax Revenue	$36	$28	$20	$13
Property Tax Revenue	$4,640	$3,620	$3,640	$2,410
Total	$4,906	$3,878	$3,890	$2,653

Table 12-85: Inland Sub-Region Per Household Revenue – Urban (Source: Strategic Economics, 2011)

Item	SF Large Lot	SF Small Lot	SF Attached	Multifamily
Vehicle License Fee Revenue	$8.23	$8.23	$8.23	$8.23
Sales Tax Revenue	$222	$222	$222	$222
Property Transfer Tax Revenue	$34	$26	$18	$12
Property Tax Revenue	$4,290	$3,340	$3,360	$2,220
Total	$4,554	$3,596	$3,608	$2,462

Table 12-86 shows the estimated revenues per acre by housing type and LDC for the Inland sub-region.

Table 12-86: Inland Sub-Region Per Acre Revenue, by Housing Type and LDC (Source: Strategic Economics, 2011)

	Standard	Compact-Greenfield	Compact-Refill	Urban
Single Family Large-Lot	$11,178	$14,315	$16,599	$15,406
Single Family Small-Lot	$22,255	$28,423	$32,963	$30,565
Single Family Attached	$49,866	$63,577	$73,670	$68,338
Multi-Family	$72,740	$92,045	$106,122	$98,481

Figure 12-20 and Figure 12-21 show the projected per household and per acre revenue for the Coastal sub-region by housing type and LDC, respectively.

Figure 12-20: Coastal Sub-Region Per Household Revenue, by LDC (Source: Strategic Economics, 2011)

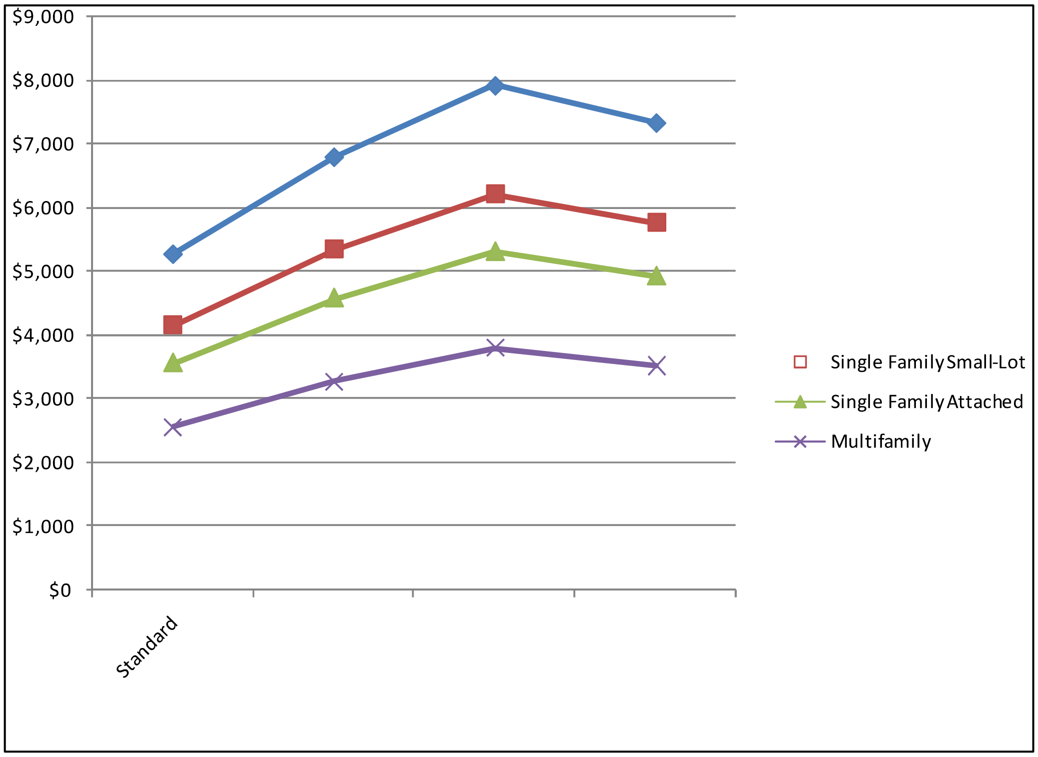


Figure 12-21: Coastal Sub-Region Per Acre Revenue, by LDC (Source: Strategic Economics, 2011)

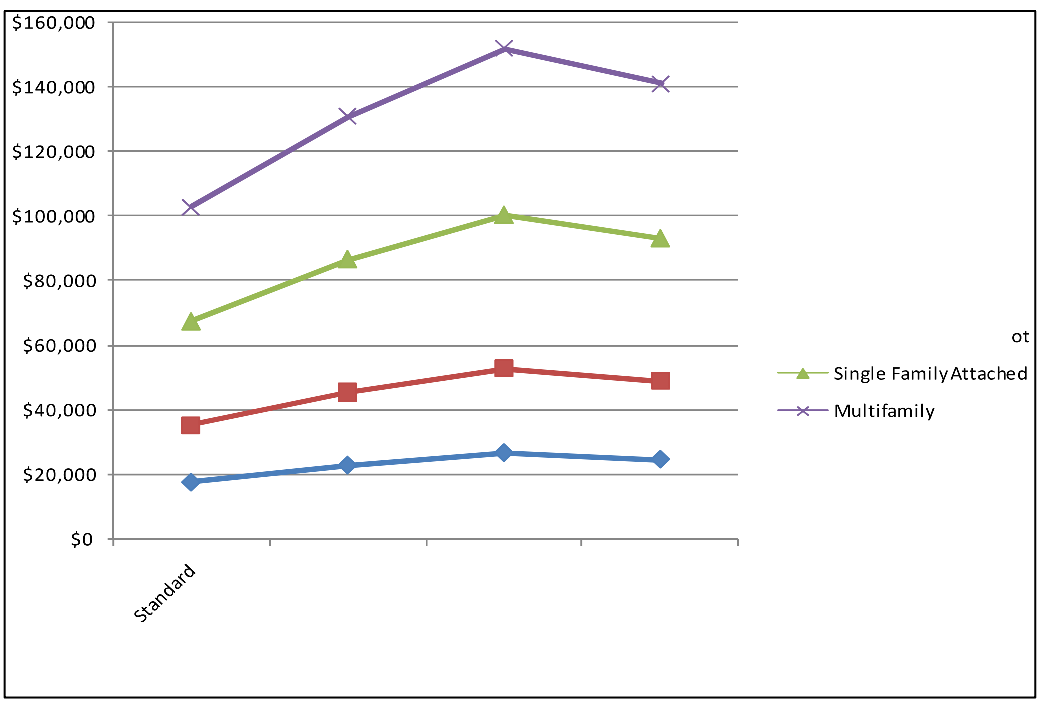


Figure 12-22 and Figure 12-23 show the projected per household and per acre revenue for the Inland sub-region by housing type and LDC, respectively.

Figure 12-22: Inland Sub-Region Per Household Revenue, by LDC (Source: Strategic Economics, 2011)

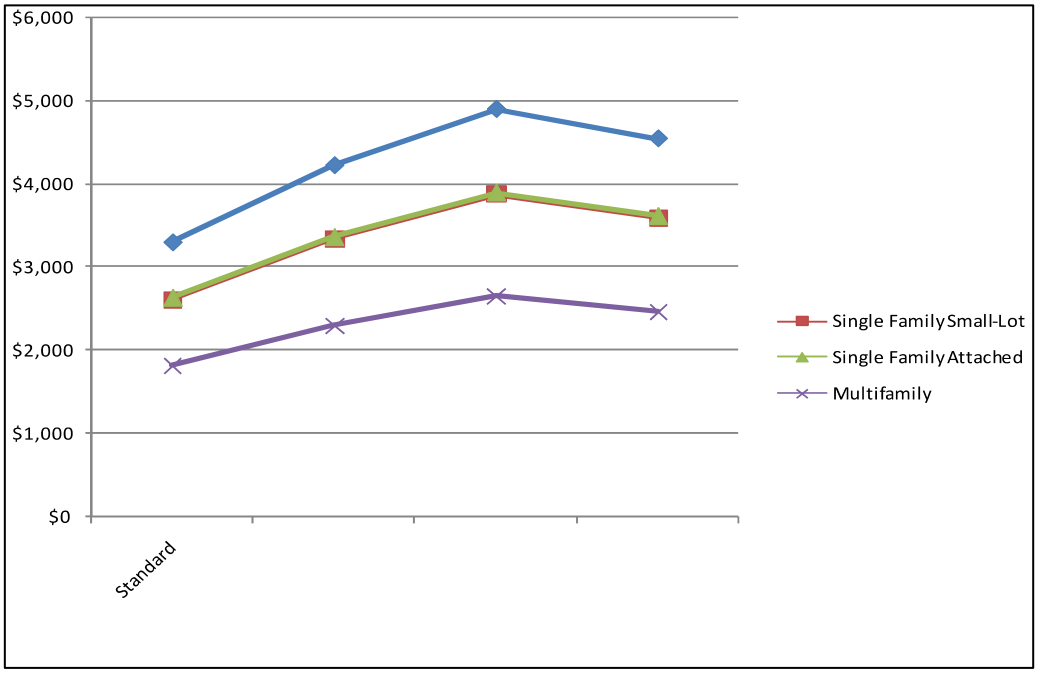
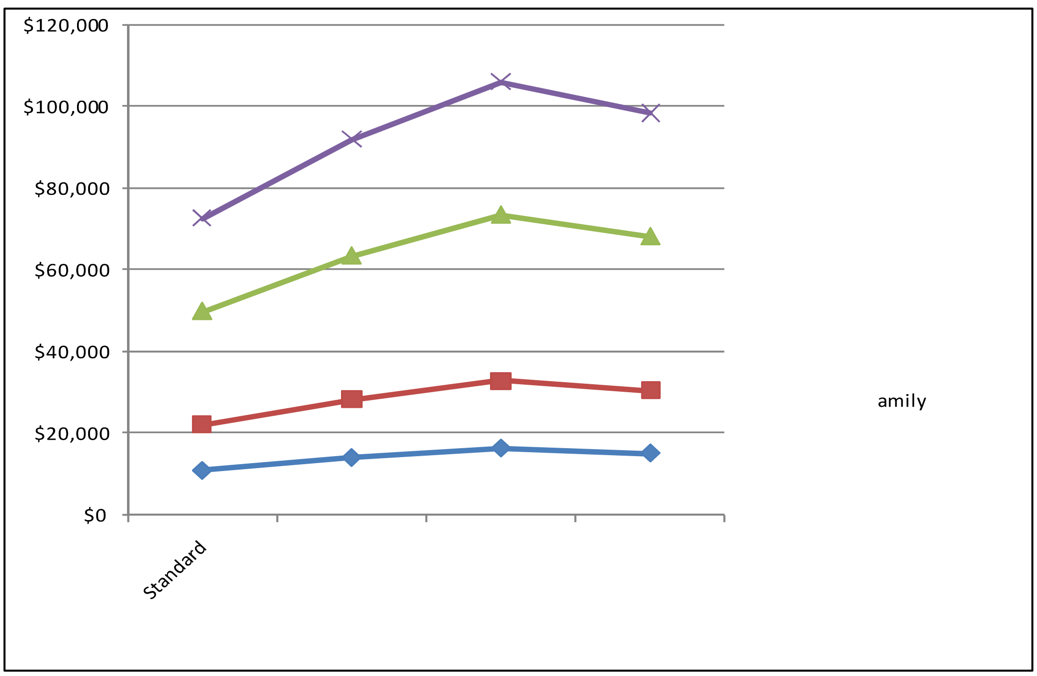


Figure 12-23: Inland Sub-Region Per Acre Revenue, by LDC (Source: Strategic Economics, 2011)



APPENDIX A
Base Data Land Use Code Crosswalks

The tables in this appendix detail the land use code "crosswalks" that were used in the base loading process for the Vision California scenarios. Crosswalks are the associations made between regional and county parcel land use codes and UrbanFootprint building types.

Not every land use code is matched directly to a building type in this table; if they are, the matching building type is listed in the "bt_id" column. The "DU" column identifies exact quantities of dwelling units to be associated with corresponding land use codes. Land use codes with a single family or multi-family flag (a 1 in the "sf_flag" or "mf_flag column) trigger a subsequent process, as described in the Seed Data Loading Methodology section that assigns a land use code to their associated type. The "min_du" and "max_du" columns establish bounds for the control totaling process; entries of "9999" in the "max_du" column allow the model to place as many dwelling units in multi-family buildings as is necessary, but do not necessarily imply that any single building will actually receive the maximum number of units. The "du_iterate_flag" field, if a Boolean '1', will model dwelling unit quantity using densities and parcels acres.

Table A-1: SANDAG Land Use Crosswalk

SANDAG Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_ flag
1000	Spaced Rural Residential		1			1		
1110	Single Family Detached		1			1		
1120	Single Family Multiple-Units			1	12		1	1
1190	Single Family Residential Without Units							
1200	Multi-Family Residential			13	9999		1	1
1280	Single Room Occupancy Units (SRO's)			1	9999		1	1
1290	Multi-Family Residential Without Units							
1300	Mobile Home Park			10	9999	1		1
1401	Jail/Prison	56						
1402	Dormitory			2	9999		1	1
1403	Military Barracks			2	99999		1	1
1404	Monastery			2	9999		1	1
1409	Other Group Quarters Facility			2	99999		1	1
1501	Hotel/Motel (Low-Rise)	38		2	999		1	1

SANDAG Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
1502	Hotel/Motel (High-Rise)	37		2	9999		1	1
1503	Resort	38		2	9999		1	1
2001	Heavy Industry	33						
2101	Industrial Park	34						
2103	Light Industry - General	34						
2104	Warehousing	36						
2105	Public Storage	42						
2201	Extractive Industry	42						
2301	Junkyard/Dump/Landfill	42						
4101	Commercial Airport	34						
4102	Military Airport	32						
4103	General Aviation Airport	32						
4104	Airstrip	34						
4111	Rail Station/Transit Center	41						
6803	Junior College	44						
4112	Freeway							
4113	Communications and Utilities	42						
4114	Parking Lot - Surface							
4115	Parking Lot - Structure	30						
4116	Park and Ride Lot							
4117	Railroad Right of Way							
4118	Road Right of Way							
4119	Other Transportation	42						
4120	Marine Terminal	42						
5001	Wholesale Trade	36						
5002	Regional Shopping Center	39						
5003	Community Shopping Center	40						
5004	Neighborhood Shopping Center	41						
5005	Specialty Commercial	41						
5006	Automobile Dealership	41						
5007	Arterial Commercial	7		0	99		1	1
5008	Service Station	41						
5009	Other Retail Trade and Strip Commercial	41						
6001	Office (High-Rise)	26						
6002	Office (Low-Rise)	27						
6003	Government Office/Civic Center	52						
6101	Cemetery	42						

SANDAG Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
6102	Religious Facility	59						
6103	Library	53						
6104	Post Office	45						
6105	Fire/Police Station	45						
6108	Mission	59						
6109	Other Public Services	45						
6501	UCSD/VA Hospital/Balboa Hospital	45						
6502	Hospital - General	45						
6509	Other Health Care	45						
6701	Military Use	32						
6702	Military Training	32						
6801	SDSU/CSU San Marcos/UCSD	43						
6802	Other University or College	44						
6804	Senior High School	51						
6805	Junior High School or Middle School	49						
6806	Elementary School	47						
6807	School District Office	27						
6809	Other School	51						
7201	Tourist Attraction	39						
7202	Stadium/Arena	41						
7203	Racetrack	41						
7204	Golf Course	41						
7205	Golf Course Clubhouse	41						
7206	Convention Center	55						
7208	Olympic Training Center	41						
7209	Casino	41						
7210	Other Recreation - High	41						
7211	Other Recreation - Low	41						
7601	Park - Active							
7603	Open Space Park or Preserve							
7604	Beach - Active							
7605	Beach - Passive							
7606	Landscape Open Space							
7607	Residential Recreation							
7609	Undevelopable Natural Area							
8001	Orchard or Vineyard	42						
8002	Intensive Agriculture	42						
8003	Field Crops	42						
9101	Vacant and Undeveloped							

SANDAG Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
	Land							
9200	Water							
9201	Bay or Lagoon							
9202	Lake/Reservoir/Large Pond							
9501	Residential Under Construction							
9502	Commercial Under Construction							
9503	Industrial Under Construction							
9504	Office Under Construction							
9505	School Under Construction							
9506	Road Under Construction							
9507	Freeway Under Construction							
9700	Mixed Use							
6703	Weapons Facility	60						
7207	Marina	34						

Table A-2: SACOG Land Use Crosswalk

SACOG Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_flag**
1	Rural Residential					1		
1A	Farm Home					1		
2	Very Low Density Residential					1		
3	Low Density Residential					1		
4	Medium Density Residential						1	
5	Medium-High Density Residential						1	
6	High Density Residential						1	
7	Urban Residential						1	
8	High-Intensity Office	25						
9	Moderate-Intensity Office	27						
10	Community/Neighborhood Retail	28						
11	Regional Retail	39						
12	Light Industrial - Office	32						
13	Light Industrial	34						
14	Heavy Industrial	33						

SACOG Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_flag**
15	Public/Quasi-Public							
16	Community/Neighborhood Commercial/Office	32						
16a	Community/Neighborhood Commercial/Office - Modified	32						
17	Regional Commercial/Office	31						
18	Mixed Use Employment Focus	7						
19	Mixed Use Residential Focus	7						
45	Intense Urban Residential	10						
46	CBD Office	25						
48	Airport	45						
49	Medical Facility	45						
50	K-12 Schools	47						
51	Colleges and Universities	44						
52	Civic/Institution	56						
53	Agricilutral Employment	42						
53	Agricultural Employment	42						
	Ag Employment	42						
	AGRICULTURAL EMPLOYMENT	42						
	AIRPORT	45						
	Civic/Institution	56						
	Institution/Civic	56						
	LARGE LOT NOT FARM HOME					1		
	Military	60						
	UC DAVIS	43						

Table A-3: SCAG Land Use Crosswalk

SCAG Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_flag**
1100	Residential			1	300	1		1
1110	Single Family Residential		1			1		
1111	High Density Single Family Residential		1			1		
1112	Low Density Single Family Residential		1			1		

SCAG Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
1120	Multi-Family Residential			1	1000		1	1
1121	Mixed Multi-Family Residential			1	100		1	1
1122	Duplexes, Triplexes and 2 or 3 unit Condominiums and Townhomes			1	100		1	1
1123	Low-Rise Apartments, Condos and Townhomes			1	100		1	1
1124	Medium-Rise Apartments and Condominiums			1	250		1	1
1125	High-Rise Apartments and Condos			1	500		1	1
1130	Mobile Homes and Trailer Parks	17				1		1
1131	Trailer Parks and Mobile Home Courts, High-Density	17						1
1132	Single Family Residential		1			1		
1140	Mixed Residential			1	100		1	1
1151	Rural Residential, High-Density		1			1		
1152	Rural Residential, Low-Density		1			1		
1200	Commercial and Services	39						
1210	General Office Use	60						
1211	Low and Medium-Rise Major Office Use	31						
1212	High-Rise Major Office Use	25						
1220	Retail Stores and Commercial Services	60						
1221	Regional Shopping Center	39						
1222	Retail Centers (Non-Strip with Contiguous Interconnected Off-Street Parking)	39						
1223	Moder Strip Development	40						
1224	Older Strip Development	40						
1231	Commercial Storage	36						
1232	Commercial Recreation	60						
1233	Hotels and Motels	37						
1234	Attended Pay Parking Facilities	30						
1240	Public Facilities	56						

SCAG Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
1241	Government Offices	56						
1242	Police and Sheriff Stations	56						
1243	Fire Stations	56						
1244	Major Medical Health Care Facilities	45						
1245	Religious Facilities	59						
1246	Other Public Facilities	60						
1247	Non-Attended Public Parking Facilities							
1251	Correctional Facilities	60		0	20000		1	1
1252	Special Care Facilities	60		0	1000		1	1
1253	Other Special Use Facilities	60		0	10000		1	1
1260	Education K-12	50						
1261	Pre-School/Day Care Centers	46						
1262	Elementary Schools	47						
1263	Junior or Intermediate High Schools	49						
1264	Senior High Schools	51						
1265	Colleges and Universities	44						
1266	Trade Schools and Professional Training Facilities	44						
1270	Military Installations	60						
1271	Military Base (Built-Up Area)	60						
1272	Military Base (Vacant Area)	60						
1273	Air Field (includes inside military bases)	60						
1274	Former Military Base (Buit-Up Area)	60						
1275	Former Military Base (Vacant Area)	60						
1276	Former Military Air Field	60						
1280	Education (corresponds to the 1260s in list) ????	46						
1290	Military Installations (corresponds to the 1270s in list) ????	60						
1300	Industrial	33						
1310	Light Industrial	34						
1311	Light Manufacturing, Assembly and Industrial	33						

SCAG Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
	Services							
1312	Picture and Television Studio Lots	32						
1313	Packing Houses and Grain Elevators	34						
1314	Research and Development	32						
1320	Heavy Industrial	33						
1321	Heavy Manufacturing	33						
1322	Petroleum Refining and Processing	34						
1323	Open Storage	36						
1324	Major Metal Processing	33						
1325	Chemical Processing	33						
1330	Mineral Extraction	42						
1331	Mineral Extraction, Other than Oil and Gas	42						
1332	Mineral Extraction, Oil and Gas	42						
1340	Wholesaling and Warehousing	35						
1400	Transportation, Communications and Utilities	34						
1410	Transportation	33						
1411	Airports	60						
1412	Railroads							
1413	Freeways and Major Roads							
1414	Park-and-Ride Lots							
1415	Bus Terminals and Yards	34						
1416	Truck Terminals	34						
1417	Harbor Facilities	34						
1420	Communication Facilities	32						
1430	Utility Facilities	34						
1431	Electrical Power Facilities	33						
1432	Solid Waste Disposal Facilities	34						
1433	Liquid Waste Disposal Facilities	34						
1434	Water Storage Facilities							
1435	Natural Gas and Petroleum	34						

SCAG Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
	Facilities							
1436	Water Transfer Facilities							
1437	Improved Flood Waterways and Structures							
1438	Mixed Utilities	34						
1440	Maintenance Yards	34						
1450	Mixed Transportation	34						
1460	Mixed Transportation and Utility	34						
1600	Mixed Urban	60						
1700	Under Construction							
1800	Open Space and Recreation	42						
1810	Golf Courses	42						
1820	Local Parks and Recreation							
1821	Developed Local Parks and Recreation	42						
1822	Undeveloped Local Parks and Recreation							
1230	Other Commercial	60						
1830	Regional Parks and Recreation							
1831	Developed Regional Parks and Recreation	42						
1832	Undeveloped Regional Parks and Rec							
1840	Cemeteries	42						
1850	Wildlife Preserves and Sanctuaries							
1860	Specimen Gardens and Arboreta	42						
1870	Beach Parks							
1880	Other Open Space and Recreation							
1900	Urban Vacant							
2000	Agriculture	42						
2100	Cropland and Improved Pasture Land	42						
2110	Irrigated Cropland and Improved Pasture Land	42						
2120	Cropland and Improved Pasture Land	42						

SCAG Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_ flag
2200	Orchards and Vineyards	42						
2300	Nurseries	42						
2400	Dairy, intensive Livestock and Associated Facilities	42						
2500	Poultry Operations	42						
2600	Other Agriculture	42						
2700	Horse Ranches	42						
3000	Vacant							
3100	Vacant Undifferentiated							
3200	Abandoned Orchards and Vineyards							
3300	Vacant with Limited Improvement							
3400	Beaches (Vacant)							
4000	Water							
4100	Water, Undifferentiated							
4400	Water within a Military Installation							
4500	Area of Inundation (High Water)							
8888	Truly Unknown							
9999	Unknown							
1213	Low Density Commercial (predominanty retail but some off and ind)	60						
1500	Mixed Commercial and Industrial	60						
4200	Harbor Water Facilities	60						
4300	Marina Water Facilities	60						

Table A-4: San Francisco Land Use Crosswalk

San Francisco Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
Commercial - Cultural/Institution al/Educational	/	53						
Commercial - Cultural/Institution al/Educational (Recreation Center)	Public Buildings (Govt) / Public Use Districts	53						
Commercial - Management/Infor mation/Prof/Svcs	Industial Warehouse / Light Industrial District	35						
Commercial - Medical	Industial Warehouse / Heavy Industrial District	35						
Commercial - Production/Distrib ution/Repair	Churches,Convents ,Rectories / Heavy Industrial District	33						
Commerical - Retail/Entertainme nt	Commercial Stores / Small Scale Neighbhd Commercial District	28						
Cultural-Institutional-Educational / Open Space	Vacant Lot / Res,One-Family Dwelling (Detached)							
Cultural-Institutional-Educational / Vacant	Vacant Lot /							
CIE__CIE__APTS	Public Buildings (Govt) / Res,Mixed Distrs,Low Density						1	
CIE__MEDCIE__	Public Buildings (Govt) / Public Use Districts	27						
CIE__MIPSCIE__	Schools / Public Use Districts	48						
CIE__MIPSPDR__	Public Buildings (Govt) / Sevice/Secondary Office District	27						

San Francisco Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
CIE__OpenSpace__APTS	Vacant Lot / Res,Mixed Distrs,Low Density							
CIE__PDR__	Port Commission Property / Community Business District	35						
CIE__PDRMIPS__	Public Buildings (Govt) / Heavy Industrial District	33						
CIE__RESCIE	Vacant Lot /							
CIE__RESIDENT__APTS	Mission Bay /						1	
CIE__RESIDENT__CONDO	Condominium / Res,Mixed Distrs,Medium Density						1	
MED__MEDMIPS__	Commercial Stores / Moderate Scale Nghbrhd Commercial Distr	28						
MED__OpenSpace__	Public Buildings (Govt) / Public Use Districts							
MIPS__MIPS__APTS	Office / Downtown General Commercial District	25						
MIPS__MIPSRETAIL/ENT__	Office / Downtown Office District	25						
MIPS__VACANT__	Office / Res,Mixed Distrs,Low Density							

San Francisco Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
MIXED__CIEMIPS__APTS	Commercial Stores / Downtown Retail District	4					1	
MIXED__CIEVISITOR__	Commercial Stores / Small Scale Neighbhd Commercial District	6					1	
MIXED__MEDVISITOR__	Commercial/Mixed use / Residential, Two-Family	7					1	
MIXED__MIPSVISITOR__	Office / Community Business District	27						
MIXED__PDR__	Port Commission Property / Light Industrial District	35						
MIXED__PDRVISITOR__	Hotels - Other / Union Street Neigh. Commercial District	37					1	
MIXED__RETAIL/ENTMIPS__CONDO	/	7					1	
MIXED__RETAIL/ENTVISITOR__	Commercial Stores / Chinatown Community Business District	6					1	
MIXED__VISITORMIPS__	Office / Sevice/Secondary Office District	27						
MIXED__VISITORPDR__	Industrial / Heavy Industrial District	33						

San Francisco Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_ flag
MIXED__VISITORRETAIL/ENT__	Commercial Stores / Downtown Retail District	28						
OpenSpace__MIPSCIE__	Public Buildings (Govt) / Public Use Districts	52					1	
OpenSpace__OpenSpace__APTS	Public Buildings (Govt) / Res,Mixed Distrs,Low Density	52						
OpenSpace__OpenSpace__CONDO	Public Buildings (Govt) / Public Use Districts							
OpenSpace__PDR__	Port Commission Property /							
OpenSpace__PDRRETAIL/ENT__	Industrial / Heavy Industrial District							
OpenSpace__RESIDENT__APTS	Coop Units Unsegregated / Residential, Two-Family							
OpenSpace__RESIDENT__CONDO	Condominium /							
OpenSpace__RESRETAIL/ENT	Condominium / Residential, Three-Family							

San Francisco Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_flag**
OpenSpace__RETAIL/ENT__	Vacant Lot - Restrictions / Chinatown Community Business District							
OpenSpace__VISITORRETAIL/ENT__	Commercial Stores /							
PDR__CIE__	Industrial / Light Industrial District	35						
PDR__MIPS__	Office / Downtown Office District	25						
PDR__OpenSpace__	Public Buildings (Govt) /							
PDR__VACANT__	Misc / Public Use Districts							
PDR__VISITOR__	Hotels - Other / Downtown Office Special District	37					1	
RESIDENT__CIE__	Public Buildings (Govt) / Res,Mixed Distrs,Low Density	7					1	
RESIDENT__MEDCIE__	Hospitals / Public Use Districts	45						
RESIDENT__OpenSpace__APTS	Apartment /						1	
RESIDENT__RESCIE	Apartment /						1	
RESIDENT__RESMIPS	Condominium /						1	

San Francisco Land Use Crosswalk

LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
RESIDENT__RESMIPS	Live/Work Condominium / Light Industrial District						1	
RESIDENT__RESRETAIL/ENT	Apartment / Res-Comm Combined Distrs,High Density						1	
RESIDENT__RESRETAIL/ENT	Commercial Store Condo / Neighbrhd Commercial Cluster District						1	
RESIDENT__VACANT__	Parking Stall Condominium / Residential, Three-Family							
RETAIL/ENT__CIE__	Public Buildings (Govt) / Public Use Districts	52						
RETAIL/ENT__MIPS__	Gas Station / Small Scale Neighbhd Commercial District	41						
RETAIL/ENT__MIPSRETAIL/ENT__	/	41						
RETAIL/ENT__PDRCIE__	Gas Station / Heavy Commercial District	40						
RETAIL/ENT__PDRRETAIL/ENT__	Commercial Stores / Small Scale Neighbhd Commercial District	28						

San Francisco Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_ flag
RETAIL/ENT__RETAIL/ENT__APTS	Commercial Stores / Res,Mixed Distrs,Medium Density	7					1	
RETAIL/ENT__RETAIL/ENT__LIVEWORK	Commercial Stores / Residential Service District	7					1	
RETAIL/ENT__RETAIL/ENTMIPS__	Gas Station / Small Scale Neighbhd Commercial District	41						
VACANT__RETAIL/ENT__	Gas Station / Res,Mixed Distrs,Moderate Density							
VISITOR__CIEMIPS__	Office / Chinatown Community Business District	28						
VISITOR__CIERETAIL/ENT__	Office / Moderate Scale Nghbrhd Commercial Distr	28						
VISITOR__MIPSPDR__	Motels / Moderate Scale Nghbrhd Commercial Distr	38					1	
VISITOR__OpenSpace__	Clubs,Lodges,Fraternal Organizations / Downtown General Commercial District							
VISITOR__PDR__	Commercial Stores / Service/Light Ind/Res District	34						

San Francisco Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_flag**
VISITOR__RESIDENT__	Timeshare / Res,Mixed Distrs,HighDensity						1	
VISITOR__RESIDENT__CONDO	Condominium /						1	
VISITOR__RETAIL/ENTCIE__	Clubs,Lodges,Fraternal Organizations / Downtown General Commercial District							
VISITOR__VACANT__	Misc / Res,Mixed Distrs,Low Density							
Mixed Commercial - Cultural/Institutional/Educational & Management/Information/Prof/Svcs	Industial Warehouse / Small Scale Neighbhd Commercial District	28					1	
Mixed Commercial - Cultural/Institutional/Educational & Medical	Industrial / Downtown Office Special District	27					1	
Mixed Commercial - Cultural/Institutional/Educational & Production/Distribution/Repair	Industial Warehouse / Small Scale Neighbhd Commercial District	35					1	
Mixed Commercial - Cultural/Institutional/Educational & Retail/Entertainment	Commercial Stores / Moderate Scale Nghbrhd Commercial Distr	28					1	

San Francisco Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
Mixed Commercial - Management/Information/Prof/Svcs & Cultural/Institutional/Education	Industrial / Heavy Industrial District	33					1	
Mixed Commercial - Management/Information/Prof/Svcs & Medical	Office / Downtown Office District	25					1	
Mixed Commercial - Management/Information/Prof/Svcs & Production/Distribution/Repair	Industial Warehouse / Heavy Industrial District	33					1	
Mixed Commercial - Management/Information/Prof/Svcs & Retail/Entertainment	Parking Lot / Neighbrhd Commercial Cluster District	29					1	
Mixed Commercial - Management/Information/Prof/Svcs & Retain/Entertainment	Port Commission Property / Heavy Industrial District	33					1	
Mixed Commercial - Medical & Cultural/Institutional/Educational	Commercial Stores / Small Scale Neighbhd Commercial District	28					1	
Mixed Commercial - Medical & Management/Information/Prof/Svcs	Industrial / Light Industrial District	33					1	
Mixed Commercial - Medical & Production/Distribution/Repair	Industrial / Light Industrial District	33					1	
Mixed Commercial - Medical & Retail/Entertainment	Industial Warehouse /	35					1	

San Francisco Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_ flag
Mixed Commercial - Production/Distribution/Repair & Cultural/Institutional/Educational	Industrial / Light Industrial District	35					1	
Mixed Commercial - Production/Distribution/Repair & Management/Information/Prof/Svcs	Vacant Lot / Light Industrial District	35					1	
Mixed Commercial - Production/Distribution/Repair & Medical	Industrial / Service/Light Ind District	35					1	
Mixed Commercial - Production/Distribution/Repair & Retail/Entertainment	Industrial / Heavy Industrial District	35					1	
Mixed Commercial - Retail/Entertainment & Cultural/Institutional/Educational	Commercial Stores / Heavy Industrial District	35					1	
Mixed Commercial - Retail/Entertainment & Management/Information/Prof/Svcs	Port Commission Property / Heavy Industrial District	33					1	
Mixed Commercial - Retail/Entertainment & Medical	Office / Small Scale Neighbhd Commercial District	28					1	
Mixed Commercial - Retail/Entertainment & Production/Distribution/Repair	Industial Warehouse / Light Industrial District	35					1	

San Francisco Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_flag**
Mixed Use - Apartments & Cultural/Institutional/Educational	Public Buildings (Govt) / Res,Mixed Distrs,Low Density	7					1	
Mixed Use - Apartments & Cultural/Institutional/Educational & Medical	Apartment / Res-Comm Combined Distrs,High Density	7					1	
Mixed Use - Apartments & Cultural/Institutional/Educational & Production/Distribution/Repair	Condominium /	7					1	
Mixed Use - Apartments & Management/Information/Prof/Svcs	Apartment / Small Scale Neighbhd Commercial District	7					1	
Mixed Use - Apartments & Management/Information/Prof/Svcs & Medical	Apartment / Res-Comm Combined Distrs,High Density	4					1	
Mixed Use - Apartments & Medical	Apartment / Neighbrhd Commercial Cluster District	7					1	
Mixed Use - Apartments & Medical & Cultural/Institutional/Educational	Misc / Valencia St. Neigh. Commercial District	6					1	
Mixed Use - Apartments & Medical & Management/Information/Prof/Svcs	Apartment / Chinatown Community Business District	6					1	
Mixed Use - Apartments & Medical & Production/Distribution/Repair	Apartmnt & Commercial Store / Small Scale Neighbhd Commercial District	7					1	

San Francisco Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_ flag
Mixed Use - Apartments & Medical & Retail/Entertainme nt	Flat & Store / North Beach Neigh. Commercial District	6					1	
Mixed Use - Apartments & Production/Distrib ution/Repair	Mission Bay / Mission Bay Office District	3					1	
Mixed Use - Apartments & Production/Distrib ution/Repair & Cultural/Institution al/Educational	Apartmnt & Commercial Store / Union Street Neigh. Commercial District	7					1	
Mixed Use - Apartments & Production/Distrib ution/Repair & Management/Infor mation/Prof/Svcs	Mixed use / Heavy Industrial District	7					1	
Mixed Use - Apartments & Production/Distrib ution/Repair & Medical	Apartment / Small Scale Neighbhd Commercial District	7					1	
Mixed Use - Apartments & Production/Distrib ution/Repair & Retail/Entertainme nt	Flat & Store / Heavy Industrial District	7					1	
Mixed Use - Apartments & Retail/Entertainme nt	Apartmnt & Commercial Store /	7					1	
Mixed Use - Apartments & Retail/Entertainme nt & Cultural/Institional /Educational	Apartment / Res-Comm Combined Distrs,High Density	2					1	
Mixed Use - Apartments & Retail/Entertainme nt & Medical	/	7					1	

San Francisco Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
Mixed Use - Apartments & Retail/Entertainment & Production/Distribution/Repair	Flats & Duplex / Small Scale Neighbhd Commercial District	7					1	
Mixed Use - Condo(s) & Cultural/Institutional/Educational	Commercial Store Condo /	7					1	
Mixed Use - Condo(s) & Cultural/Institutional/Educational & Production/Distribution/Repair	Condominium /	7					1	
Mixed Use - Condo(s) & Management/Information/Prof/Svcs	/	7					1	
Mixed Use - Condo(s) & Management/Information/Prof/Svcs & Medical	Condominium /	7					1	
Mixed Use - Condo(s) & Medical	Commercial Stores /	7					1	
Mixed Use - Condo(s) & Medical & Cultural/Institutional/Educational	Condominium /	7					1	
Mixed Use - Condo(s) & Medical & Management/Information/Prof/Svcs	Condominium / Chinatown Res/Nghbrhd Commercial Distr	6					1	
Mixed Use - Condo(s) & Medical & Production/Distribution/Repair	Condominium / Res-Comm Combined Distrs,High Density	3					1	
Mixed Use - Condo(s) & Medical & Retail/Entertainment	Condominium / Chinatown Res/Nghbrhd Commercial Distr	6					1	

San Francisco Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_flag**
Mixed Use - Condo(s) & Production/Distribution/Repair	Condominium / Light Industrial District	7					1	
Mixed Use - Condo(s) & Production/Distribution/Repair & Cultural/Institutional/Educational	Condominium / Neighbrhd Commercial Cluster District	7					1	
Mixed Use - Condo(s) & Production/Distribution/Repair & Management/Information/Prof/Svcs	Condominium /	7					1	
Mixed Use - Condo(s) & Production/Distribution/Repair & Retail/Entertainment	Condominium /	7					1	
Mixed Use - Condo(s) & Retail/Entertainment	Condominium / Moderate Scale Nghbrhd Commercial Distr	7					1	
Mixed Use - Condo(s) & Retail/Entertainment & Cultural/Institional/Educational	Condominium /	7					1	
Mixed Use - Condo(s) & Retail/Entertainment & Medical	Condominium /	7					1	
Mixed Use - Condo(s) & Retail/Entertainment & Production/Distribution/Repair	Condominium / Heavy Industrial District	7					1	
Mixed Use - Cultural/Institutional/Educational & Management/Information/Prof/Svcs & Apartments	Commercial Stores / Heavy Industrial District	7					1	

San Francisco Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
Mixed Use - Cultural/Institutional/Educational & Management/Information/Prof/Svcs & Condo(s)	Condominium / Res-Comm Combined Distrs,High Density	4					1	
Mixed Use - Cultural/Institutional/Educational & Management/Information/Prof/Svcs & Flat(s)	Flat & Store / Chinatown Res/Nghbrhd Commercial Distr	6					1	
Mixed Use - Cultural/Institutional/Educational & Management/Information/Prof/Svcs & Live-Work	Live/Work Condominium /	6					1	
Mixed Use - Cultural/Institutional/Educational & Management/Information/Prof/Svcs & Single Family	Dwelling / Residential, Two-Family	7					1	
Mixed Use - Cultural/Institutional/Educational & Management/Information/Prof/Svcs & SROs	Commercial Stores / Chinatown Res/Nghbrhd Commercial Distr	6					1	
Mixed Use - Cultural/Institutional/Educational & Retail/Entertainment & Apartments	Apartment /	4					1	
Mixed Use - Cultural/Institutional/Educational & Retail/Entertainment & Condo(s)	Condominium BMR /	7					1	
Mixed Use - Cultural/Institutional/Educational & Retail/Entertainment & Flat(s)	Office - Condominium /	6					1	

San Francisco Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_flag**
Mixed Use - Cultural/Institutional/Educational & Retail/Entertainment & Live-Work	Industrial / Service/Light Ind District	7					1	
Mixed Use - Cultural/Institutional/Educational & Retail/Entertainment & Single Family	Dwelling / Residential, Two-Family	7					1	
Mixed Use - Cultural/Institutional/Educational & Retail/Entertainment & SROs	Hotels - Other / Chinatown Visitor Retail District	6					1	
Mixed Use - Flat(s) & Cultural/Institutional/Educational	Flat & Store / Moderate Scale Nghbrhd Commercial Distr	6					1	
Mixed Use - Flat(s) & Cultural/Institutional/Educational & Medical	Flat & Store / Union Street Neigh. Commercial District	6					1	
Mixed Use - Flat(s) & Cultural/Institutional/Educational & Production/Distribution/Repair	Flat & Store / Service/Light Ind District	7					1	
Mixed Use - Flat(s) & Management/Information/Prof/Svcs	Flat & Store / Moderate Scale Nghbrhd Commercial Distr	6					1	
Mixed Use - Flat(s) & Management/Information/Prof/Svcs & Medical	Flat & Store / Chinatown Community Business District	6					1	
Mixed Use - Flat(s) & Medical	Flat & Store / Chinatown Visitor Retail District	6					1	
Mixed Use - Flat(s) & Medical & Cultural/Institutional/Educational	Flat & Store / Chinatown Community Business District	6					1	

San Francisco Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_flag**
Mixed Use - Flat(s) & Medical & Management/Information/Prof/Svcs	Flat & Store / Small Scale Neighbhd Commercial District	7					1	
Mixed Use - Flat(s) & Medical & Production/Distribution/Repair	Flat & Store / Res-Comm Combined Distrs,Medium Density	6					1	
Mixed Use - Flat(s) & Medical & Retail/Entertainment	Flat & Store / North Beach Neigh. Commercial District	6					1	
Mixed Use - Flat(s) & Production/Distribution/Repair	Flat & Store / Small Scale Neighbhd Commercial District	7					1	
Mixed Use - Flat(s) & Production/Distribution/Repair & Cultural/Institutional/Educational	Flat & Store / North Beach Neigh. Commercial District	6					1	
Mixed Use - Flat(s) & Production/Distribution/Repair & Management/Information/Prof/Svcs	Live/Work Condominium /	7					1	
Mixed Use - Flat(s) & Production/Distribution/Repair & Retail/Entertainment	Flat & Store / Moderate Scale Nghbrhd Commercial Distr	6					1	
Mixed Use - Flat(s) & Retail/Entertainment	Flat & Store / Small Scale Neighbhd Commercial District	7					1	
Mixed Use - Flat(s) & Retail/Entertainment & Cultural/Institional/Educational	Flat & Store / Neighbrhd Commercial Cluster District	7					1	
Mixed Use - Flat(s) & Retail/Entertainment & Medical	Flat & Store /	7					1	

San Francisco Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
Mixed Use - Flat(s) & Retail/Entertainment & Production/Distribution/Repair	Flat & Store / Light Industrial District	7					1	
Mixed Use - Live-Work	Live/Work Condominium / Heavy Industrial District	7					1	
Mixed Use - Live-Work & Cultural/Institutional/Educational	Commercial Stores / Service/Light Ind District	7					1	
Mixed Use - Live-Work & Cultural/Institutional/Educational & Production/Distribution/Repair	Commercial Store Condo /	7					1	
Mixed Use - Live-Work & Management/Information/Prof/Svcs	Live/Work Condominium /	7					1	
Mixed Use - Live-Work & Management/Information/Prof/Svcs & Medical	Live/Work Condominium / Sevice/Secondary Office District	7					1	
Mixed Use - Live-Work & Medical	Condominium / Heavy Industrial District	7					1	
Mixed Use - Live-Work & Medical & Management/Information/Prof/Svcs	Condominium /	7					1	
Mixed Use - Live-Work & Production/Distribution/Repair	Industrial / Heavy Industrial District	7					1	
Mixed Use - Live-Work & Production/Distribution/Repair & Management/Information/Prof/Svcs	Live/Work Condominium /	7					1	

San Francisco Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
Mixed Use - Live-Work & Production/Distribution/Repair & Retail/Entertainment	Live/Work Condominium /	7					1	
Mixed Use - Live-Work & Retail/Entertainment	Live/Work Condominium / Heavy Industrial District	7					1	
Mixed Use - Live-Work & Retail/Entertainment & Production/Distribution/Repair	/	7					1	
Mixed Use - Management/Information/Prof/Svcs & Cultural/Institutional/Educational & Apartments	Public Buildings (Govt) / Res,Mixed Distrs,Low Density	7					1	
Mixed Use - Management/Information/Prof/Svcs & Cultural/Institutional/Educational & Condo(s)	Apartmnt & Commercial Store / Light Industrial District	7					1	
Mixed Use - Management/Information/Prof/Svcs & Cultural/Institutional/Educational & Flat(s)	Flats & Duplex / Residential, Three-Family	7					1	
Mixed Use - Management/Information/Prof/Svcs & Cultural/Institutional/Educational & Live-Work	Live/Work Condominium /	7					1	
Mixed Use - Management/Information/Prof/Svcs & Cultural/Institutional/Educational & Single Family	Dwelling / Residential, One-Family	7					1	

San Francisco Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
Mixed Use - Management/Information/Prof/Svcs & Cultural/Institutional/Educational & SROs	Office / Chinatown Visitor Retail District	6					1	
Mixed Use - Management/Information/Prof/Svcs & Production/Distribution/Repair & Apartments	/ Heavy Industrial District	7					1	
Mixed Use - Management/Information/Prof/Svcs & Production/Distribution/Repair & Condo(s)	Condominium / Heavy Industrial District	7					1	
Mixed Use - Management/Information/Prof/Svcs & Production/Distribution/Repair & Flat(s)	Flat & Store / Small Scale Neighbhd Commercial District	7					1	
Mixed Use - Management/Information/Prof/Svcs & Production/Distribution/Repair & Live-Work	Live/Work Condominium /	7					1	
Mixed Use - Management/Information/Prof/Svcs & Production/Distribution/Repair & Single Family	Dwelling / South Park District	6					1	
Mixed Use - Management/Information/Prof/Svcs & Production/Distribution/Repair & SROs	Hotels - Other / Res,Mixed Distrs,HighDensity	3					1	
Mixed Use - Management/Information/Prof/Svcs & Retail/Entertainment & Apartments	Flat & Store / Residential, Three-Family	6					1	

San Francisco Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
Mixed Use - Management/Information/Prof/Svcs & Retail/Entertainment & Condo(s)	Commercial Store Condo / Light Industrial District	7					1	
Mixed Use - Management/Information/Prof/Svcs & Retail/Entertainment & Flat(s)	Flat & Store / Light Industrial District	7					1	
Mixed Use - Management/Information/Prof/Svcs & Retail/Entertainment & Live-Work	Condominium / Light Industrial District	7					1	
Mixed Use - Management/Information/Prof/Svcs & Retail/Entertainment & Single Family	Dwelling / South Park District	7					1	
Mixed Use - Management/Information/Prof/Svcs & Retail/Entertainment & SROs	Hotels - Other / Broadway Neigh. Commercial District	7					1	
Mixed Use - Retail/Entertainment & Flat(s)	Flat & Store / Small Scale Neighbhd Commercial District	7					1	
Mixed Use - Retail/Entertainment & Management/Information/Prof/Svcs & Apartments	Apartmnt & Commercial Store / Small Scale Neighbhd Commercial District	7					1	
Mixed Use - Retail/Entertainment & Management/Information/Prof/Svcs & Condo(s)	Live/Work Condominium /	7					1	
Mixed Use - Retail/Entertainment & Management/Information/Prof/Svcs & Flat(s)	Flat & Store / Moderate Scale Nghbrhd Commercial Distr	6					1	

San Francisco Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_flag**
Mixed Use - Retail/Entertainment & Management/Information/Prof/Svcs & Live-Work	Live/Work Condominium /	7					1	
Mixed Use - Retail/Entertainment & Management/Information/Prof/Svcs & SROs	Hotels - Other / Downtown Office District	3					1	
Mixed Use - Single Family & Cultural/Institutional/Educational	Dwelling / Residential, Two-Family					1		
Mixed Use - Single Family & Cultural/Institutional/Educational & Medical	Dwelling / Residential, Three-Family					1		
Mixed Use - Single Family & Cultural/Institutional/Educational & Production/Distribution/Repair	Dwelling / Residential, Two-Family					1		
Mixed Use - Single Family & Management/Information/Prof/Svcs	Dwelling / Heavy Industrial District	7					1	
Mixed Use - Single Family & Management/Information/Prof/Svcs & Medical	2 Dwellings on One Parcel / Small Scale Neighbhd Commercial District	7					1	
Mixed Use - Single Family & Medical	Dwelling / Small Scale Neighbhd Commercial District	7					1	
Mixed Use - Single Family & Medical & Management/Information/Prof/Svcs	Dwelling / Residential Service District	7					1	
Mixed Use - Single Family & Production/Distribution/Repair	Dwelling / Light Industrial District	7					1	

San Francisco Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_ flag
Mixed Use - Single Family & Production/Distribution/Repair & Management/Information/Prof/Svcs	Industrial /	7					1	
Mixed Use - Single Family & Production/Distribution/Repair & Medical	Dwelling / Small Scale Neighbhd Commercial District	7					1	
Mixed Use - Single Family & Retail/Entertainment	Dwelling / Residential, Two-Family	7					1	
Mixed Use - Small Commercial & Flat(s)	Flats & Duplex / Public Use Districts	7					1	
Mixed Use - SROs & Cultural/Institutional/Educational	Hotels - Other / Broadway Neigh. Commercial District	3					1	
Mixed Use - SROs & Cultural/Institutional/Educational & Production/Distribution/Repair	Office / Service/Light Ind District	3					1	
Mixed Use - SROs & Management/Information/Prof/Svcs	Flat & Store / Service/Light Ind District	3					1	
Mixed Use - SROs & Management/Information/Prof/Svcs & Medical	Motels / Residential, One-Family	3					1	
Mixed Use - SROs & Medical	Hotels - Other / Chinatown Community Business District	3					1	
Mixed Use - SROs & Medical & Cultural/Institutional/Educational	Hotels - Other / Chinatown Res/Nghbrhd Commercial Distr	3					1	

San Francisco Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
Mixed Use - SROs & Medical & Management/Information/Prof/Svcs	Hotels - Other / Service/Light Ind/Res District	3					1	
Mixed Use - SROs & Medical & Retail/Entertainment	Hotels - Other / Res-Comm Combined Distrs,High Density	3					1	
Mixed Use - SROs & Production/Distribution/Repair	Hotels - Other / Service/Light Ind/Res District	3					1	
Mixed Use - SROs & Production/Distribution/Repair & Retail/Entertainment	Commercial Stores / Service/Light Ind District	3					1	
Mixed Use - SROs & Retail/Entertainment	Hotels - Other / Small Scale Neighbhd Commercial District	3					1	
Mixed Use - SROs & Retail/Entertainment & Cultural/Institional /Educational	Hotels - Other / Broadway Neigh. Commercial District	3					1	
Mixed Use - SROs & Retail/Entertainment & Medical	Hotels - Other / Downtown Office District	3					1	
Mixed Use - SROs & Retail/Entertainment & Production/Distribution/Repair	Hotels - Other / Moderate Scale Nghbrhd Commercial Distr	3					1	
Mixed Use - Visitor Accomodations & Cultural/Institutional/Educational	Hotel / Residential, Two-Family	7					1	
Mixed Use - Visitor Accomodations & Management/Information/Prof/Svcs	Clubs,Lodges,Fraternal Organizations / Downtown Office District	37					1	

San Francisco Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
Mixed Use - Visitor Accomodations & Medical	Hotels - Other / Res-Comm Combined Distrs,High Density	37					1	
Mixed Use - Visitor Accomodations & Production/Distrib ution/Repair	Hotel Commercial (H2w/Com) / Service/Light Ind/Res District	37					1	
Mixed Use - Visitor Accomodations & Retail/Entertainme nt	Hotel / Downtown Office District	37					1	
Mixed Use - Visitor Accomodations & Retail/Entertainme nt & Management/Infor mation/Prof/Svcs	Hotels - Other / Downtown Retail District	37					1	
No Use Code - Appears to be Mixed Use	/	7					1	
Open Space	Vacant Lot / Public Use Districts							
Residential - Apartments	Apartment / Small Scale Neighbhd Commercial District	7					1	
Residential - Condominium(s)	Condominium / Res,Mixed Distrs,Low Density	7					1	
Residential - Flats	Flats & Duplex / Residential, One-Family					1		
Residential - Single Family	Dwelling / Res,One-Fam w/minor 2nd Unit					1		
Residential - SRO(s)	Hotels - Other / Heavy Industrial District	38					1	
Residential (unknown type)	Condominium BMR / Res,Mixed Distrs,Low Density					1		
Vacant	/							

San Francisco Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
Visitor Accomodations	Hotels - Other / Small Scale Neighbhd Commercial District	38					1	
Water	Vacant Lot / Res,One-Family Dwelling (Detached)							

Table A-5: San Francisco BayArea Land Use Crosswalk

San Francisco Bay Area Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
5	Unspecified Water							
11	Unspecified Residential						1	1
12	Unspecified Commercial and Services	41						
13	Unspecified Industrial	34						
14	Unspecified Transportation Communication and Utilities							
15	Mixed Commercial and Industrial	60					1	1
16	Mixed Residential			1	350		1	1
17	Unspecified Urban Open							
21	Cropland and Pasture	42						
22	Orchards, Groves, Vineyards, Nurseries	42						
23	Confined Feeding	42						
24	Farmsteads and Agricultural Buildings	42						
31	Herbaceous Rangeland							
32	Shrub and Brush Rangeland							
33	Mixed Rangeland							
41	Deciduous Forest							
42	Evergreen Forest							
43	Mixed Forest							

San Francisco Bay Area Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_flag**
51	Streams and Canals							
52	Lakes							
53	Reservoirs							
54	Bays and Estuaries							
55	Sedimentation Pond							
56	Water on USGS Base Maps but Land on Other Maps							
61	Forested Wetlands							
62	Nonforested Wetlands							
63	Salt Evaporation Ponds							
64	Land on USGS Base Maps but Wetland on Other Maps							
72	Beaches							
73	Sand Other Than Beaches							
74	Bare Exposed Rock							
75	Strip Mines, Quarries, Gravel Pits	42						
76	Transitional Areas							
77	Mixed Sparsely Vegetated Land							
111	1-5 acres/unit		1			1		
112	.334-1 acres/unit		1			1		
113	.126-.333 acres/unit		1			1		
114	Mobile Homes and Mobile Home Parks					1		1
115	Less than .126 acre lots		1			1		
118	Group Quarters			1	35000		1	1
119	Common Facilities							
121	Retail and Wholesale, Post Offices	41						
122	Intensive Outdoor Recreation	42						
123	Education	49						
124	Hospitals, Rehabilitation, Health, and State Prison Fa	45						
125	Unspecified Military	60					1	1

San Francisco Bay Area Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
126	Unspecified Institutional Facilities	60					1	1
127	Research Centers	32						
128	Office	32						
129	Hotels and Motels	38		2	1000		1	1
131	Heavy Industrial	33						
132	Light industrial	34						
134	Food Processing	33						
135	Warehousing	35						
141	Road Transportation Facilities	42						
142	Rail Transportation Facilities	42						
143	Unspecified Airport	60						
144	Marine Transportation Facilities	36						
147	Municipal Water Supply Facilities	42						
148	Communication Facilities	42						
161	Mixed Residential and Commercial-Separate Buildings	7					1	1
162	Mixed Residential and Commercial-Single Building	6					1	1
171	Extensive Recreation							
172	Cemetery	42						
173	Urban Park	42						
174	Open Space-Slated for Redevelopment							
175	Undeveloped Vacant Land							
211	Cropland	42						
212	Pasture	42						
221	Orchard or Groves	42						
222	Vineyards and Kiwi Fruit	42						
223	Greenhouses and Floriculture, Wholesale Nurseries	42						
311	Protected Herbaceous Rangeland							

San Francisco Bay Area Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_flag**
321	Protected Shrub and Brush Rangeland							
331	Protected Mixed Rangeland	42						
411	Protected Deciduous Forest							
421	Protected Evergreen Forest							
431	Protected Mixed Forest							
561	Residential on Water (Arks)					1		1
563	Industrial Ports and Piers	42						
751	Strip Mines and Quarries	42						
752	Earthworks not Associated with a Commercial Operation							
761	Sanitary Land Fills	42						
762	Other Transitional	42						
1231	Primary Schools	48						
1232	Colleges and Universities	43						
1233	Stadiums	41						
1234	University Housing	13		2	3000		1	1
1235	Day Care Facilities	40						
1241	Designated Trauma Centers	45						
1242	Community Hospitals (not Designated Trauma Centers)	45						
1243	Medical Long-Term Care Facilities	45					1	1
1244	Medical Clinics	45						
1246	Out-Patient Surgery Centers	45						
1247	State Prisons	45					1	1
1248	State Mental Health and Developmentally Disabled Facil	45					1	1
1249	State Psychiatric Facilities	45					1	1
1251	Military Residential	45					1	1
1253	General Military Use	60					1	1
1254	Military Hospital	45						

San Francisco Bay Area Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_flag**
1255	Military Communications	60						
1256	Military Airport	60						
1257	Military Open Areas	42						
1258	Military Port	36						
1259	Closed Military Facilities	60						
1261	Stadium (not associated with a college or university)	41						
1262	Religious Institution	59						
1263	Fire Station	56						
1264	Police Station	56						
1265	City Halls, County, State, Federal Government Centers	56						
1267	Local Government Jails and Rehabilitation Centers	45					1	1
1268	Convention Centers	55						
1269	Museums, Libraries, Community Centers	53						
1411	Freeways, Highways, and Interchanges							
1413	Park and Ride Lots							
1414	Truck or Bus Maintenance Yard	60						
1415	City, County, or Utility Corporation Yard	60						
1416	Parking Garages and Lots	42						
1417	Inspection and Weigh Stations	60						
1418	Local Streets and Roads							
1421	Rail Passenger Stations	60						
1422	Rail Yards	42						
1431	Commercial Airport Passenger Terminal	60						
1432	Commercial Airport Air Cargo Facility	60						
1433	Commercial Airport Airline Maintenance	60						
1434	Commercial Airport Runway	60						
1435	Commercial Airport	60						

San Francisco Bay Area Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
	Utilities							
1436	Commercial Airport-Other	60						
1437	General Aviation (public) Airfield	60						
1438	Private Airfield	60						
1441	Commercial Port Passenger Terminal	60						
1442	Commercial Port Container Terminal	36						
1443	Commercial Port Oil and Liquid Bulk Terminal	36						
1444	Commercial Port-Other Terminal and Ship Repair	36						
1445	Commercial Port Storage and Warehousing	36						
1446	Tow Boat (Tug) Facility	36						
1447	Ferry Terminal	41						
1448	Marina	60						
1451	Electricity-Power Plant	34						
1452	Electricity-Substation	42						
1453	Electricity-Other	42						
1461	Wastewater Treatment Plant	34						
1462	Wastewater Pumping Station	42						
1463	Wastewater Storage	42						
1471	Water Treatment Plant	34						
1472	Water Pumping Station	42						
1473	Water Storage-Covered	42						
1474	Water Storage-Open	42						
1483	Media Broadcast Tower and Communication Facilities	42						
1711	Golf Course	42						
1712	Racetrack	41						
1713	Campground	42						
1751	Vacant Residential							
1752	Vacant Commercial							
1753	Vacant Industrial							

San Francisco Bay Area Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
2111	Row Crops	42						
2112	Small Grains	42						

Table A-6: Fresno County Land Use Crosswalk

Fresno County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
0	Vacant							
1	Single Family, 1 Unit		1			1		
10	Single Family, 1 Unit		1			1		
0M1	Manufactured Home 1 Unit		1			1		
A01	Apartment 1 Unit		1				1	
A02	Apartment 2 Unit		2				1	
A03	Apartment 3 Unit		3				1	
A04	Apartment 4 Unit		4				1	
A05	Apartment 5 Unit		5				1	
A06	Apartment 6 Unit		6				1	
A07	Apartment 7 Unit		7				1	
A08	Apartment 8 Unit		8				1	
A09	Apartment 9 Unit		9				1	
A10	Apartment 10 Unit		10				1	
A11	Apartment 11 Unit		11				1	
A12	Apartment 12 Unit		12				1	
A13	Apartment 13 Unit		13				1	
A14	Apartment 14 Unit		14				1	
A15	Apartment 15 Unit		15				1	
A16	Apartment 16 Unit		16				1	
A17	Apartment 17 Unit		17				1	
A18	Apartment 18 Unit		18				1	
A19	Apartment 19 Unit		19				1	
A20	Apartment 20 Unit		20				1	
A21	Apartment 21 Unit		21				1	
A22	Apartment 22 Unit		22				1	
A23	Apartment 23 Unit		23				1	
A24	Apartment 24 Unit		24				1	

Fresno County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
A25	Apartment 25 Unit		25				1	
A26	Apartment 26 Unit		26				1	
A27	Apartment 27 Unit		27				1	
A28	Apartment 28 Unit		28				1	
A29	Apartment 29 Unit		29				1	
A30	Apartment 30 Unit		30				1	
A31	Apartment 31 Unit		31				1	
A32	Apartment 32 Unit		32				1	
A33	Apartment 33 Unit		33				1	
A34	Apartment 34 Unit		34				1	
A35	Apartment 35 Unit		35				1	
A36	Apartment 36 Unit		36				1	
A37	Apartment 37 Unit		37				1	
A38	Apartment 38 Unit		38				1	
A39	Apartment 39 Unit		39				1	
A40	Apartment 40 Unit		40				1	
A41	Apartment 41 Unit		41				1	
A42	Apartment 42 Unit		42				1	
A43	Apartment 43 Unit		43				1	
A44	Apartment 44 Unit		44				1	
A46	Apartment 46 Unit		46				1	
A48	Apartment 48 Unit		48				1	
A49	Apartment 49 Unit		49				1	
A50	Apartment 50 Unit		50				1	
A51	Apartment 51 Unit		51				1	
A52	Apartment 52 Unit		52				1	
A53	Apartment 53 Unit		53				1	
A54	Apartment 54 Unit		54				1	
A55	Apartment 55 Unit		55				1	
A56	Apartment 56 Unit		56				1	
A57	Apartment 57 Unit		57				1	
A58	Apartment 58 Unit		58				1	
A59	Apartment 59 Unit		59				1	
A60	Apartment 60 Unit		60				1	
A61	Apartment 61 Unit		61				1	

Fresno County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
A62	Apartment 62 Unit		62				1	
A63	Apartment 63 Unit		63				1	
A64	Apartment 64 Unit		64				1	
A66	Apartment 66 Unit		66				1	
A68	Apartment 68 Unit		68				1	
A70	Apartment 70 Unit		70				1	
A72	Apartment 72 Unit		72				1	
A73	Apartment 73 Unit		73				1	
A74	Apartment 74 Unit		74				1	
A75	Apartment 75 Unit		75				1	
A76	Apartment 76 Unit		76				1	
A79	Apartment 79 Unit		79				1	
A80	Apartment 80 Unit		80				1	
A81	Apartment 81 Unit		81				1	
A82	Apartment 82 Unit		82				1	
A84	Apartment 84 Unit		84				1	
A86	Apartment 86 Unit		86				1	
A88	Apartment 88 Unit		88				1	
A90	Apartment 90 Unit		90				1	
A92	Apartment 92 Unit		92				1	
A93	Apartment 93 Unit		93				1	
A96	Apartment 96 Unit		96				1	
A99	Apartment 99+ Unit		99				1	
ALM	Agriculture: Almonds	42						
AO2	Apartment 2 Units		2				1	
APP	Agriculture: Apples	42						
APR	Agriculture: Apricots	42						
APX	Agriculture: Apples	42						
ASC	Auto Service Center & New Car Sales	40						
ASP	Agriculture: Asparagus	42						
BOA	Bowling Alley	40						
BUS	Agriculture: Bushberries	42						
CAW	Car Wash	40						
CHE	Agriculture: Cherries	42						

Fresno County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
CHU	Church	59						
CLH	Club House	40						
COG	Industry/Agriculture: Cotton Gin & Compress	34						
COH	Convalescent Hospital	43						
COS	Cold Storage & Slaughter House	34						
CS1	Commercial Store 1 Unit	40						
CS2	Commercial Store 2 Unit	40						
CS3	Commercial Store 3 Unit	40						
CS4	Commercial Store 4 Unit	40						
CS5	Commercial Store 5 Unit	40						
CS6	Commercial Store 6 Unit	40						
CS7	Commercial Store 7 Unit	40						
CS8	Commercial Store 8 Unit	40						
CS9	Commercial Store 9 Unit	40						
CSG	Commercial Store	40						
CSI	Commercial Store	40						
D1H	Commercial Store: Discount House	40						
D24	Agriculture: Pasture	42						
DAI	Agriculture: Dairy	42						
DES	Commercial Store: Department Store	28						
DIH	Commercial Store: Discount House	40						
DRY	Agriculture: Dry Farming	42						
EUC	Agriculture: Eucalyptus Grove	42						
EXO	Agriculture: Exotic	42						
FAC	Industrial: Factory	34						
FEE	Agriculture: Feed Lot	42						
FIE	Agriculture: Field	42						

Fresno County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
	Cropland							
FIG	Agriculture: Figs	42						
FII	Commercial	40						
FRL	Fraternal Lodge	40						
FTM	Freight Truck Terminal	34						
FUH	Funeral Home	40						
G01	General Office 1 Unit	31						
G02	General Office 2 Unit	31						
G03	General Office 3 Unit	31						
G04	General Office 4 Unit	31						
G05	General Office 5 Unit	29						
G09	General Office 9 Unit	29						
GAR	Garage	40						
GD1	General Office 1 Unit	31						
GO0	General Office	31						
GO1	General Office 1 Unit	31						
GO2	General Office 2 Unit	31						
GO3	General Office 3 Unit	31						
GO4	General Office 4 Unit	31						
GO5	General Office 5 Unit	31						
GO6	General Office 6 Unit	31						
GO7	General Office 7 Unit	31						
GO8	General Office 8 Unit	31						
GO9	General Office 9 Unit	31						
GOC	Golf Course	42						
GOI	General Office I	31						
GRA	Industrial/Warehousing Low Density	34						
H85	Hotel 85 Units	37						
H86	Hotel 86 Units	37						
H99	Hotel 99+ Units	37						
HOH	Agriculture: Hot House	42						
HOS	Hospital	45						
KIW	Agriculture: Kiwi	42						
LAB	Labor Housing		1			1		
LEM	Agriculture: Lemons	42						

Fresno County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
LII	Light Industrial	34						
LIM	Light Manufacturing	34						
LUY	Lumber Yard	34						
M01	Motel 1 Unit	37						
M02	Motel 2 Units	37						
M04	Motel 4 Units	37						
M06	Motel 6 Units	37						
M08	Motel 8 Units	37						
M10	Motel 10 Units	37						
M11	Motel 11 Units	37						
M12	Motel 12 Units	37						
M14	Motel 14 Units	37						
M17	Motel 17 Units	37						
M18	Motel 18 Units	37						
M20	Motel 20 Units	37						
M21	Motel 21 Units	37						
M22	Motel 22 Units	37						
M23	Motel 23 Units	37						
M24	Motel 24 Units	37						
M28	Motel 28 Units	37						
M30	Motel 30 Units	37						
M31	Motel 31 Units	37						
M34	Motel 34 Units	37						
M37	Motel 37 Units	37						
M44	Motel 44 Units	37						
M47	Motel 47 Units	37						
M48	Motel 48 Units	37						
M52	Motel 52 Units	37						
M53	Motel 53 Units	37						
M58	Motel 58 Units	37						
M59	Motel 59 Units	37						
M60	Motel 60 Units	37						
M70	Motel 70 Units	37						
M85	Motel 85 Units	37						
M87	Motel 87 Units	37						

Fresno County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_flag**
M99	Motel 99+ Units	37						
MD1	Medical-Dental Office 1 Unit	31						
MD2	Medical-Dental Office 2 Units	31						
MD3	Medical-Dental Office 3 Units	31						
MD4	Medical-Dental Office 4 Units	31						
MD5	Medical-Dental Office 5 Units	31						
MD6	Medical-Dental Office 6 Units	31						
MD7	Medical-Dental Office 7 Units	31						
MD8	Medical-Dental Office 8 Units	31						
MD9	Medical-Dental Office 9 Units	31						
MDI	Medical-Dental Office I	31						
MH1	Manufactured Home on Permanent Foundation 1 Unit		1			1		
MH2	Manufactured Home on Permanent Foundation 2 Units		1			1		
MH3	Manufactured Home on Permanent Foundation 3 Units		1			1		
MHI	Manufactured Home on Permanent Foundation I		1			1		
MHP	Manufactured Home Park		1			1		
MIN	Mine	42						
MNS	Mini Storage	40						
MO1	Medical Office 1 Unit	31						
NEC	Agriculture: Nectarines	42						
NUR	Agriculture: Nursery	42						
OIL	Oil & Gas	42						
OLI	Agriculture: Olives	42						
OM0	Manufactured Home		1			1		
OM1	Manufactured Home 1 Unit		1			1		

Fresno County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
OM2	Manufactured Home 2 Units		2			1		
OM3	Manufactured Home 3 Units		3			1		
OM4	Manufactured Home 4 Units		4			1		
OMI	Manufactured Home I		1			1		
OOO	Vacant							
ORA	Agriculture: Oranges	42						
OUT	Outlot & Common Area							
P0S	Potential Primary Subdivision							
PAH	Agricultural Industrial: Packing House	34						
PAS	Agriculture: Native Pasture	42						
PC1	Partially Completed Residential Single Family							
PCI	Partially Completed Improvements							
PEA	Agriculture: Peaches	42						
PEC	Agriculture: Pecans	42						
PER	Agriculture: Persimmons	42						
PIS	Agriculture: Pistachios	42						
PLU	Agriculture: Plums	42						
PND	Ponding Basin							
POM	Agriculture: Pomegranates	42						
POS	Potential Subdivision (Primary)							
POU	Agriculture: Poultry	42						
PRS	Agriculture: Pears	42						
PRU	Agriculture: Prunes	42						
PSL	Parking/Sales Lot (Used Cars)	40						
PUB	Publicly Owned							
REC	Recreation	42						
RES	Restaurant	28						
S00	Single Family Residential		1			1		

Fresno County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_flag**
S01	Single Family Residential 1 Unit		1			1		
S02	Single Family Residential 2 Units		2			1		
S03	Single Family Residential 3 Units		3			1		
S04	Single Family Residential 4 Units		4			1		
S05	Single Family Residential 5 Units		5			1		
S06	Single Family Residential 6 Units		6			1		
S08	Single Family Residential 8 Units		8			1		
S09	Single Family Residential 9 Units		9			1		
S10	Single Family Residential 10 Units		10			1		
S16	Single Family Residential 16 Units		16			1		
SCC	Shopping Center (Community)	40						
SCH	School & Day Nursery	46						
SCN	Shopping Center (Neighborhood)	40						
SCQ	Shopping Center (Mini)	40						
SCR	Shopping Center (Regional)	39						
SES	Service Station	40						
SFS	Small Convenience Food Store	40						
SGP	Sand-Gravel Pit	42						
SM1	Single Family Manufactured Home 1 Unit		1			1		
SM2	Single Family Manufactured Home 2 Units		2			1		
SM3	Single Family Manufactured Home 3 Units		3			1		
SM4	Single Family Manufactured Home 4 Units		4			1		
SM6	Single Family		6			1		

Fresno County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_flag**
	Manufactured Home 6 Units							
SO1	Single Family Residential 1 Unit		1			1		
SOH	Sorority (Social) House		1				1	
SS0	Suburban & Country Store	40						
SS1	Suburban & Country Store 1 Unit	40						
SS2	Suburban & Country Store 2 Units	40						
SS3	Suburban & Country Store 3 Units	40						
STA	Agriculture: Stables	42						
SUM	Super Market	40						
THE	Theater	40						
TIM	Agriculture: Timberland	42						
TPZ	Agriculture: Timber Preserve Zone	42						
TRX	Agriculture: Trees, Mixed	42						
TTT	Temporary Use Code							
TUX	Agriculture: Trees/Vines Mixed	42						
TVX	Agriculture: Trees -- Vines Mixed	42						
TWR	Vacant							
VIR	Agriculture: Vines, Raisin Variety	42						
VIT	Agriculture: Vines, Table Variety	42						
VIW	Agriculture: Vines, Wine Variety	42						
VIX	Agriculture: Vines, Mixed	42						
VLM	Vacant Land with only Minor Improvements							
WAC	Water Company	42						
WAH	Warehouse	35						
WAL	Agriculture: Walnuts	42						
WAR	Water Rights							
WIN	Winery	34						

Fresno County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_flag**
XMA	Agriculture: Xmas Tree Farm	42						
XXX	Other							

Table A-7: Kern County Land Use Crosswalk

Kern County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_flag**
0	NO USE CODE (INTERIM STATUS)							
1	A OR RS ZONE ONE ACRE OR LESS		1			1		
9	SAME AS 0001 W/MINOR MISC IMP		1			1		
10	R1 ZONE ONE ACRE OR LESS		1			1		
17	SAME AS 0010 W/LICENSED MH		1			1		
19	R1 ZONE W/MISC IMP		1			1		
20	R2 ZONE		1			1		
27	SAME AS 0020 W/LICENSED MH		1			1		
29	R2 ZONE W/MISC IMP		1			1		
30	R3 ZONE		1			1		
39	R3 ZONE W/MISC IMPS		1			1		
40	R4 ZONE		1			1		
49	R4 ZONE W/MISC IMPS		1			1		
50	E ZONED LAND ONE ACRE OR LESS		1			1		
59	SAME AS 0050 W/MISC IMP		1			1		
60	VAC>1AC <3 NO R2 3 4 COMM IND							
67	SAME AS 0060 W/LIC MH		1			1		
68	SAME AS 0060 W/LIC MHS		1			1		
69	SAME AS 0060 W/MISC IMP	42						
70	VAC=3 AC <7 NO R2 3 4 COMM IND							
77	SAME AS 0070 W/LIC MH		1			1		
79	SAME AS 0070 W/MISC IMPS	42						

Kern County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_
80	VAC 7-20 AC NO R2 3 4 COMM IND							
81	20-40 AC NO R2 3 4 COMM IND							
82	40-100 AC NO R2 3 4 COMM IND							
83	100< NO R2 3 4 COMM IND							
87	SAME AS 0080 W/LIC MH		1			1		
88	VACANT LAND - RENEWABLE ENERGY	42						
89	7-20AC W/MISC	42						
90	VAC ALL T ZONE INCL T RST R1T	42						
91	VAC W/MANUFTD HOME SUBDIVISION					1		1
97	MS & T ZONING W/LIC MH		1			1		
98	SAME AS 0097 W/2+ LIC MH		2			1		
99	VAC T W/MISC IMP NO LIC MH							
100	SGL FAM RES ON RS ZONED LAND		1			1		
101	SGL FAM RES ON R1 ZONED LAND		1			1		
102	SGL FAM RES ON R2 ZONED LAND		1			1		
103	SGL FAM RES ON R3 ZONED LAND		1			1		
104	SGL FAM RES ON R4 ZONED LAND		1			1		
105	SGL FAM RES ON COMM/IND ZONE		1			1		
106	SFR <20AC NOT ON RS 1 2 3 4		1			1		
107	SGL FAM RES + 1 LICENSED MH					1		1
108	SGL FAM RES W/2+ LICENSED MH					1		1
180	MH NO PERM FOUNDATION MS ZONE		1			1		
181	SAME AS 0180 NO T RST R1T ZONE		1			1		
182	SAME AS 0180 NO A SERIES ZONE		1			1		
183	0180 ALL Z NO MS T RST R1T A Z		1			1		

Kern County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_
186	SAME AS 0106 W/LIC MHS		1			1		
189	MLTP MHS ANY ZN NO PERM FOUND					1		1
190	MH PERM FOUND MS ZONING		1			1		
191	SAME AS 0190 NO T RST R1T ZONE		1			1		
192	SAME AS 0190 A SERIES ZONING		1			1		
193	0190 ALL Z NO MS T RST R1T Z		1			1		
196	SAME AS 0106 W/MISC IMP		1			1		
198	SAME AS 0190 W/LIC MHS		1			1		
199	MLTP MHS W/PERM FOUN ANY ZONE					1		1
200	DUPLEX OR 2 LIV UN 1 PARCEL		2				1	
201	2 SEPARATE RES ON 1 PARCEL		2				1	
207	SAME AS 0200 W/LIC MHS		2			1		
300	TRIPLEX OR 3 LIV UN ON 1 PARC		3				1	
301	DUPLEX + 1 RES = 3 LIV UN		3				1	
302	PARCEL W/3 SEPARATE RES		3				1	
307	SAME AS 0300-0302 W/MH							
400	FOURPLEX OR 4 LIV UN ON 1 PARC		4				1	
401	2 DUPLEXES ON 1 PARCEL		4				1	
402	TRIPLEX + 1 RES ON 1 PARCEL		4				1	
403	1 PARCEL W/4 SEPARATE RES		4				1	
404	DUPLEX + 2 RESIDENCES		4				1	
407	SAME AS 0400 W/LIC MH		4			1		
601	COMMON AREA							
700	SFR ON R2/3/4 LAND, LOT<6000SF		1			1		
800	NOT USED							
1000	VAC C-O ZONE							
1007	SAME AS 1000 W/LIC MH		1			1		
1009	SAME AS 1000 W/MIS	42						

Kern County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_
	IMPS							
1010	VAC C-1 ZONE							
1019	SAME AS 1010 W/MISC IMPS	42						
1020	VAC C-2 ZONE							
1027	SAME AS 1020 W/LIC MH		1			1		
1029	SAME AS 1000-1020 W/ MULT. MH		2			1		
1030	UNKNOWN USE							
1090	SAME AS 1000 W/MISC IMP	42						
1100	SMALL STREET RETAIL < 5000 SF	40						
1111	LIQUOR	40						
1116	AUTO PARTS	40						
1119	BARBER/BEAUTY	40						
1120	LAUNDRY/DRY CLEANING	40						
1123	FREESTANDING RETAIL <5000 SF	40						
1124	IN-LINE MULTI-TENANT <5000 SF	40						
1125	RETAIL PAD IN CENTER <5000 SF	40						
1190	MULTIPLE USE STORE	40						
1200	COMBO STORES & OFFICES	40						
1202	COMBO STORE & OFFICE	40						
1290	SAME AS 1200 W/MISC IMP	40						
1300	LARGE STREET RETAIL > 5000 SF	39						
1301	DEPARTMENT	39						
1308	FREESTANDING RETAIL BLDG >5000	39						
1309	IN-LINE RETAIL BLDG >5000	39						
1310	PAD IN SHOPPING CENTER >5000SF	40						
1311	INDOOR SWAP MEET >5000 SF	40						
1312	BIG BOX RETAIL >15000 SF	40						
1390	MULTIPLE USE	60						
1400	MARKETS	40						

Kern County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_
1401	SUPERMARKET	40						
1402	GROCERY	40						
1403	FRANCHISE FOOD (7-11 CIRCLE-K)	40						
1404	MEAT RETAIL	40						
1405	PRODUCE	40						
1406	SEAFOOD	40						
1407	FRUIT STAND	40						
1490	MULTI USE	40						
1500	SHOPPING CENTER	40						
1501	SMALL SHOPPING CENTER	40						
1502	LARGE REGIONAL SHOPPING CENTER	39						
1600	OFFICE BLDGS	31						
1601	MEDIA	31						
1604	COMMUNICATION SERVICE	31						
1605	MEDICAL	31						
1606	DENTAL	31						
1607	MEDICAL-DENTAL COMBO	31						
1613	VETERINARY	31						
1690	MULTIPLE USE	60						
1700	INSTITUTIONAL	45						
1701	HOSPITAL	45						
1702	PSYCHIATRIC HOSPITAL	45						
1703	ASSISTED LIVING	45						
1704	MEDICAL LAB	31						
1705	AMBULANCE SVC	45						
1706	CHURCH	59						
1707	CEMETARY							
1708	MORTUARY							
1709	MAUSOLEUM							
1710	PRIVATE SCHOOL	47						
1711	CHURCH OWNED	59						
1712	INDEPENDENT LIVING	38					1	1
1713	DAY CARE CENTER	45						
1714	HALF-WAY HOUSE						1	1
1715	MUSEUM	45						

Kern County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_
1716	DETENTION FACILITY/PRISON							
1720	SKILLED NURSING	45						
1790	INSTITUTIONAL W/MISC IMPS	45						
1800	FOOD/BEVERAGE	41						
1801	RESTAURANTS	41						
1802	CAFES	41						
1803	COFFEE SHOP	41						
1804	COCKTAIL LOUNGE	41						
1805	BAR OR TAVERN	41						
1806	CATERING	41						
1807	DRIVE-IN	41						
1808	SPECIALTY DRIVE UPS	41						
1890	MULTI-USE FOOD/BEVERAGE	41						
1900	RECREATIONAL	42						
1901	THEATER (ENCLOSED)	28						
1903	POOL HALL	41						
1904	HEALTH/SPA	41						
1905	BOWLING ALLEY	41						
1906	SKATING RINK	41						
1908	FRATERNAL ORG	41						
1909	COUNTRY CLUB	42						
1910	GOLF COURSE	42						
1911	TENNIS CLUB	42						
1912	RECREATION OR MEETING HALL	42						
1913	LODGE/RESORT	42						
1914	AUTO RACETRACK	42						
1916	HORSE RACETRACK	42						
1917	DANCE STUDIO	41						
1918	HANDBALL/RAQUETBALL COURTS							
1919	DRIVING RANGE	42						
1980	RECREATIONAL W/LIC MHS	42	1			1		
1990	RECREATIONAL W/MISC IMP	42						
2100	FINANCIAL	31						

Kern County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_**
2101	BANK	31						
2102	SAVINGS & LOAN	31						
2103	BAIL BOND	31						
2190	FINANCIAL W/MISC IMP	31						
2200	SERVICE/REPAIR SHOPS	40						
2201	CAR WASH	41						
2202	KENNEL/PET GROOMING	41						
2203	AUTO BODY/PAINT	41						
2204	AUTO REPAIR/GARAGE	41						
2205	MOTORCYCLE REPAIR	41						
2206	BICYCLE REPAIR	41						
2207	EQUIPMENT REPAIR	41						
2208	BUS DEPOT	36						
2290	MULTI USE SERVICE/REPAIR SHOPS	3634						
2300	PETROLEUM	34						
2301	SERVICE STATION	34						
2302	BULK PLANT	34						
2303	BOTTLED GAS DLR	34						
2304	GAS & MINI-MART	41						
2305	MINI-MART SS/FAST FOOD	41						
2390	MULTI USE PETROLEUM RELATED	41						
2400	SALES-MOTOR VEH	41						
2401	AUTO SALES NEW	41						
2402	AUTO SALES USED	41						
2403	BOAT SALES	41						
2405	FARM MACHINERY SALES	41						
2406	RV SALES	41						
2490	MULTI USE AUTOMOTIVE RELATED	41						
2500	COMM/IND COMMON AREA							
2501	PARKING LOT							
2590	MULTI USE PARKING RELATED							
2600	NURSERIES	3042						
2601	NURSERIES	42						
2603	TREE SERVICE	42						

Kern County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_
2604	SEED GROWERS	42						
2605	PEST CONTROL	42						
2606	HYDROPONICS/GREENHO USES	42						
2607	TREE FARM NOT NURSERY STOCK	42						
2608	ORCHARD NURSERIES	42						
2690	MULTI USE HORTICULTURE RELATED	42						
2700	HOTEL	37					1	1
2701	HOTEL W/O RESTAURANT	37					1	1
2707	ROOMING HOUSE	37					1	1
2790	HOTEL RELATED W/MISC IMP	37					1	1
2800	MOTEL	37					1	1
2801	MOTEL W/O RESTAURANT	37					1	1
2890	MOTEL RELATED W/MISC IMP	37					1	1
2900	MANUFACTURED HOME PARK	17				1		1
2901	RV/TRAILER PARK	17				1		1
2990	MANUFTD HOME PARK W/MISC IMPS	17				1		1
3000	VACANT LAND INDUSTRIAL							
3010	VACANT M-1							
3019	M1 W/MISC IMPS	42						
3020	VACANT M-2							
3027	SAME AS 3020 W/LIC MH		1			1		
3029	M2 W/MISC IMPS	42						
3030	VACANT M-3							
3039	M3 W/MISC IMPS	42						
3050	RAILROAD SPUR							
3080	SAME AS 3000 W/LIC MHS		1			1		
3089	SAME AS 3080 W/MISC IMP	42						
3090	SAME AS 3000 W/MISC IMP	42						
3100	LIGHT MFG	33						
3101	CONTRACTOR - GENERAL BLDG	33						
3102	CONTRACTOR - SWIMMING POOL	33						

Kern County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_**
3103	CONTRACTOR - ENGINEERING	33						
3104	CONTRACTOR - DRILLING	33						
3105	CONTRACTOR - OILFIELD	33						
3106	MACHINE SHOP	33						
3107	TIRESHOP - RETREAD	33						
3108	RECYCLING CENTER	33						
3120	OFFICE/WAREHOUSE MULTI UNIT	33						
3180	SAME AS 3100 W/LIC MHS	33						
3190	INDUSTRIAL MULTI-USE	33						
3200	HEAVY INDUSTRIAL	33						
3202	STEEL FABRICATION	33						
3203	HEAVY EQUIPMENT-MFG	33						
3204	CARBON PLANT	33						
3205	CONCRETE AND/OR BATCH PLANTS	33						
3206	REFINERIES	33						
3280	SAME AS 3200 W/LIC MHS	33						
3290	SAME AS 3200 W/MISC IMP	33						
3300	TIMBER	42						
3301	LUMBER YARD	33						
3400	PRODUCE PLANT	33						
3401	COTTON GIN	42						
3402	PACKING SHED	33						
3490	MULTI USE	33						
3500	FOOD PROCESSING	33						
3501	BAKERY	33						
3503	BOTTLING PLANT	33						
3504	MEAT PACKING	33						
3505	WINERY	42						
3506	ALMOND HULLER	33						
3507	DAIRY DISTRIBUTORSHIP	33						
3508	SOFT DRINK DIST	33						
3509	ALCOHOLIC BEBERAGE DIST	33						
3590	MULTI USE	60						
3600	STORAGE (ENCLOSED)	36						

Kern County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_
3601	WAREHOUSE	36						
3602	PUBLIC STORAGE (MINI WHSE)	36						
3603	VAN & STORAGE	36						
3604	ICE/COLD STORAGE	36						
3605	GRAIN ELEVATOR OR SILO	42						
3700	STORAGE (FENCED W/ SMALL OFF)	42						
3701	EQUIPMENT RENTAL	42						
3702	AUTO WRECKING	42						
3703	METAL SALVAGE	42						
3704	FARM EQUIPMENT	42						
3705	TRUCKING COMPANY	42						
3706	TRUCK TERMINAL	42						
3707	TOWING COMPANY	42						
3709	COMMUTER SERVICE	42						
3710	JUNK YARD	42						
3720	DISTRIBUTION CENTERS	34						
3780	SAME AS 3700 W/LIC MHS		1			1		
3790	MULTI USE	60						
3800	INDUSTRIAL SALES	34						
3880	SAME AS 3800 W/LIC MHS		1			1		
3890	SAME AS 3800 W/MISC IMP	34						
3900	AIRPARKS	60						
3901	LANDING STRIP (AIRCRAFT)	60						
3902	ANTENNAS/TOWERS	42						
3960	ENERGY GENERATION	42						
3961	WIND PARK	42						
3962	SOLAR PARK	42						
3964	COAL	34						
3968	CO-GENERATION PLANT NAT GAS	34						
3969	CO-GENERATION PLANT BIOMASS	34						
3984	CO-GEN COAL FIRED OIL RELATED	34						
3988	CO-GEN GAS FIRED OIL RELATED	34						

Kern County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_
4000	UNDEVELOPED LAND >20AC							
4001	UNKNOWN USE							
4002	UNKNOWN USE							
4020	UNKNOWN USE							
4100	ORCHARDS	42						
4101	UNKNOWN USE							
4190	UNKNOWN USE							
4200	VINEYARDS	42						
4290	UNKNOWN USE							
4300	IRRIGATED LAND	42						
4301	UNKNOWN USE							
4390	UNKNOWN USE							
4400	GRAZING OR DRY FARM LAND	42						
4401	UNKNOWN USE							
4480	UNKNOWN USE							
4490	UNKNOWN USE							
4500	DAIRY	42						
4600	FEEDLOT	42						
4700	AGRICULTURAL/IND. COMPLEX	34						
4800	LIVESTOCK	42						
4801	CATTLE	42						
4802	HORSES	42						
4900	RANCH HDQTRS	42						
4908	FARM LABOR CAMPS	32				1		1
5000	UNDEVELOPED LAND >20AC MT/DES							
5001	SAME AS 5000 W/S FAM RES		1			1		
5002	SAME AS 5000 W/(2+) S FAM RES					1		1
5007	UNKNOWN USE							
5008	UNKNOWN USE							
5009	SAME AS 5000 W/MISC IMP	42						
5080	>20AC W/OIL	42						
5090	UNKNOWN USE							
5097	UNKNOWN USE							

Kern County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_
5098	UNKNOWN USE							
5100	VAC DESERT LAND SUB TO PROP 8							
6000	U S A							
6010	STATE OF CALIFORNIA							
6020	COUNTY OF KERN							
6030	INCORPORATED CITY							
6040	SCHOOL OWNED	47						
6050	SPECIAL DISTRICTS							
6060	REDEVELOPMENT AGENCY							
6100	ASSESSORS UTILITY PARCELS							
6200	CITY OF LOS ANGELES NON-EXEMPT							
6201	OTHER NON-EXEMPT GOVT PRPTY							
6300	NO VAL-SUMP ETC							
6301	SAME AS 6300 EXCEPT <$1000							
6302	SAME AS 6300 EXCEPT >$1000							
6309	PRIVATE DOMESTIC WTR WELL SITE							
6400	COMMUNICATION TOWER SITE	42						
6900	NOT USED							
7000	TOXIC HAZARD PRESENT ON SITE							
8100	MINE & QUARRIES	42						
8101	BORAX	42						
8102	CEMENT PLANT	34						
8103	SAND & GRAVEL	42						
8104	GYPSUM	42						
8105	ALL OTHER TYPES	42						
8201	PRODUCTIVE MINERAL RIGHTS	42						
8203	OIL PUMPING STATION	42						
8209	SAME AS 8200 W/MISC IMP	42						
8300	WATER COMPANIES	33						
8301	PUBLIC UTILITY	42						
8302	MUTUAL WATER	42						

Kern County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_
	COMPANY							
8303	PRIVATE WATER COMPANY	42						
8304	WATER RIGHTS	42						
8305	CANALS							
8306	COMMUNITY WATER SYSTEM							
8400	MINING CLIAMS							
8401	PATENTED							
8409	SAME AS 8400 W/MISC IMP	42						
8490	SAME AS 8400 W/MISC IMP	42						
8700	HAZARDOUS WATE DISPOSAL SITE	42						
8702	HAZ WASTE DUMP CLASS II	42						
8703	NON-HAZ DUMP	42						
8704	PRIVATE SEWAGE DUMP	42						
9021	COMMERCIAL PI-KERN	42						
9201	COMMERCIAL IMP UNSECURED NO PI	42						
500	1 PARCEL W/5-9 UNIT COMPLEX		7				1	
501	1 PARCEL W/10-20 UNIT COMPLEX		15				1	
502	1 PARCEL W/21-30 UNIT COMPLEX		25				1	
503	1 PARCEL W/(31+) UNIT COMPLEX		40				1	
504	1 PARCEL W/(5+) RES COMBO = 5		5				1	
602	COOPERATIVE HOUSING						1	1
600	CONDO, TOWNHOUSE, OR PUD						1	1
1201	COMBO RESIDENCE & OFFICE	6				1		1
1203	COMBO RESIDENCE & STORE	6				1		1
1614	OFFICE/RESIDENCE COMBINATION	6						1

Table A-8: Kings County Land Use Crosswalk

Kings County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_flag**
1100	FIELD CROPS	42						
1110	FIELD CROPS & 1 SFR	42	1			1		
1120	FIELDS CROPS & >1 SFR	42	4			1		
1130	FIELD CROPS & 1 SFR & MH(S)	42	4			1		
1140	FIELD CROPS & > 1 SFR & MH(S)	42	4			1		
1150	FIELD CROPS & MH(S)	42	4			1		
1170	FIELD CROPS + MH ON PF	42	1			1		
1190	FIELD CROPS & MISC IMP	42						
1300	IRRIGATED PASTURE	42						
1310	IRRIGATED PASTURE & 1 SFR	42	1			1		
1320	IRRIGATED PASTURE & > 1 SFR	42	4			1		
1330	IRRIGATED PASTURE & 1 SFR & MH	42	2			1		
1340								
1350	IRRIGATED PASTURE & MH(S)	42	4			1		
1390	IRRG/PAST & MISC IMP	42						
1500	TREES & VINES	42						
1510	TREES & VINES & 1 SFR	42	1			1		
1520	TREES & VINES & > 1 SFR	42	4			1		
1530	TREES & VINES & 1 SFR & MH(S)	42	2			1		
1540	TREES & VINES & > 1 SFR & MH(S)	42	3			1		
1550	TREES & VINES & MH(S)	42	4			1		
1570	TREES & VINES + MH ON PF	42	1			1		
1590	TREES & VINES & MISC IMP	42						
1700	AG LAND TO ALTERNATE USE	42						
1710	AG/TRANSITIONAL & 1 SFR	42	1			1		
1720	AG/TRANSITIONAL & > 1 SFR	42	4			1		
1790	AG/TRANSITIONAL & MISC IMP	42						
1800								
1810								
1830								
1850	BEE/HONEY PROC & MH(S)	42	4			1		
1890	BEE/HONEY PROC & MISC IMP	42						
1900	RURAL HOMESITES/VACANT							

Kings County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
1910	RURAL HOMESITES & 1 SFR		1			1		
1920	RURAL HOMESITES & > 1 SFR		4			1		
1930	RURAL HOMESITES & 1 SFR & MH'S		3			1		
1940	RURAL HOMESITES & > 1 SFR & MH(S)		4			1		
1950	RURAL HOMESITES & MH(S)		4			1		
1970	RURAL HOMESITES + MH ON PF		1			1		
1990	RURAL HOMESITES & MISC IMP							
2100	DAIRIES							
2110	DAIRIES & 1 SFR	42	1			1		
2120	DAIRIES & > 1 SFR	42	3			1		
2130	DAIRIES & 1 SFR & MH'S	42	3			1		
2140	DAIRIES & > 1 SFR & MH(S)	42	3			1		
2150	DAIRIES & MH(S)	42	4			1		
2170								
2190	DAIRIES & MISC IMP	42						
2300	GRAZING LAND	42						
2310	GRAZING LAND & 1 SFR	42	1			1		
2320	GRAZING LAND & > 1 SFR	42	4			1		
2330								
2340								
2350	GRAZING LAND & MH(S)	42	4			1		
2370			1			1		
2390	GRAZING LAND & MISC IMP	42						
2400	DRY FARMING	42						
2410	DRY FARMING & 1 SFR	42	1			1		
2430								
2450	DRY FARMING & MH(S)	42	3			1		
2490	DRY FARMING & MISC IMP	42						
2590								
2600								
2610	CATTLE FEED LOT & 1 SFR	42	1			1		
2620	CATTLE FEED LOT & > 1 SFR	42	3			1		
2630	CATTLE FEED LOT & MH'S	42	4			1		
2650	CATTLE FEED LOT & MH(S)	42	4			1		

Kings County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
2690	CATTLE FEED LOT & MISC IMP	42						
2700	POULTRY	42						
2710	POULTRY & 1 SFR	42	1			1		
2720	POULTRY & > 1 SFR	42	4			1		
2740								
2750	POULTRY & MH(S)	42	4			1		
3100	STORE - SMALL GROCERY/OFFICE	40						
3110	STORE S/GROCERY/OFFICE & 1 SFR	40	1			1		
3120	STORE S/GROC/OFF & > 1 SFR	40	4			1		
3150	STORE S/GROCERY/OFF & MH(S)	40	4			1		
3200	STORE/OFFICE COMBINATIONS	40						
3210	STORE/OFFICE COMBO & 1 SFR	40	1			1		
3220								
3290								
3300	DEPARTMENT/GENERAL STORES	40						
3330								
3400	SUPERMARKETS	40						
3500	SHOPPING CENTERS/NEIGHBORHOOD	40						
3510								
3560	NEIGHBOR/SHOPPING CNTR/CONDO	10					1	1
3600	SHOPPING CENTERS/REGIONAL	40						
3700	COMMERCIAL LOT TO ALT USE	42						
3710	COMM-TRANS & 1 SFR	42	1			1		
3720	COMM-TRANS & > 1 SFR	42	4			1		
3750								
3790	COMM-TRANS & MISC IMP	42						
3800	MOBILE HOME PARK	18						
3810	MOBILE HOME PARK & 1 SFR	18	2					
3900	PROFESSIONAL BUILDING	31						
3910	PROFESSIONAL BUILDING & 1 SFR	31	1			1		
3950	PROFESSIONAL BUILDING & MH(S)	31	4			1		

Kings County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
4100	RESTAURANTS/LOUNGES/CAFES	41						
4110	RESTAURANTS/LOUNGES/CAFES & 1 SFR	41	1			1		
4120	RESTAURANTS/LOUNGES/CAFES & > 1 SFR	41	4			1		
4160								
4190	RESTAURANTS/LOUNGES/CAFES & MISC IMP	41						
4200	RECREATION	42						
4210								
4250	RECREATION & MH(S)	42	4			1		
4290	RECREATION & MISC IMP	42						
4300	BANKS/SAVINGS & LOANS	31						
4400	SERVICE SHOPS	40						
4410	SERVICE SHOPS & 1 SFR	40	1			1		
4420	SERVICE SHOPS & > 1 SFR	40	2			1		
4450	SERVICE SHOPS & MH(S)	40	4			1		
4490	SERVICE SHOPS & MISC IMP	40						
4500	FARM MACHINERY SALES/STORAGE	40						
4510								
4550								
4590	FARM MACHINERY SALES/STORAGE & MISC IMP	40						
4600	WHOLESALE OUTLET	41						
4700	NURSERIES/GREENHOUSES	33						
4710		33	1			1		
4800	SERVICE STATIONS	40						
4810	SERVICE STATIONS & 1 SFR	40	1			1		
4850		40	1			1		
4900	PARKING LOTS							
4990	PARKING LOTS & MISC IMPS							
5100	LIGHT MANUFACTURING	33						
5110	LIGHT MANUFACTURING & 1 SFR	33	1			1		
5150	LIGHT MANUFACTURING & MH(S)	33	1			1		
5190	LIGHT MANUFACTURING & MISC IMPS	33						

Kings County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_flag**
5200	HEAVY INDUSTRIAL	33						
5300	LUMBER YARDS/PLANING MILLS	33						
5400	PACKING SHED/COLD STORAGE	33						
5500	FOOD PROCESSING	33						
5510	FOOD PROCESSING & 1 SFR	33	1					
5600	WAREHOUSING/ICE PLANT/GRAIN EL	36						
5610	WAREHOUSING/ICE PLANT/GRAIN EL & 1 SFR	36	1					
5690	WAREHOUSING/ICE PLANT/GRAIN EL & MISC IMPS	36						
5700	OPEN STORAGE	36						
5710								
5720								
5750								
5790	OPEN STORAGE & MISC IMPS	42						
5800	COTTON GINS	42						
5810	COTTON GINS & 1 SFR	42	1			1		
5900	COMMERCIAL/INDUST VACANT LOTS							
5910	COMMERCIAL/INDUST VACANT LOTS & 1 SFR		1			1		
5950	COMMERCIAL/INDUST VACANT LOTS & MH(S)		3			1		
5990	COMMERCIAL/INDUST VACANT LOTS & MISC IMPS							
6100	COMMUNICATIONS	42						
6200	MOTOR VEHICLE DEALERS NEW/USED	41						
6220								
6300	TRANSPORTATION	34						
6390	TRANSPORTATION & MISC IMP	34						
6400	HOTELS/MOTELS	37						
6490	HOTELS/MOTELS & MISC IMP	37						
6500	MINI-MART/SERVICE STATION	40						
6600	MULTIPLE UNITS/APARTMENTS						1	1
6610	MULTIPLE UNITS/APARTMENTS & 1 SFR						1	1
6620	MULTIPLE UNITS/APARTMENTS & > 1 SFR						1	1

Kings County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
6640								
6700	AUTO PARTS/REPAIR SHOPS	41						
8100	CHURCHES	59						
8110	CHURCHES & 1 SFR	59	1			1		
8150	CHURCHES & MH(S)	59	3			1		
8200	HOSPITALS	45						
8300	CONVALESCENT HOMES / REST HOMES	45					1	1
8400	MORTUARIES / CEMETERIES	42						
8500	SCHOOLS / MUSEUMS	49						
8510								
8520								
8550	SCHOOLS / MUSEUMS & MH(S)	49	4			1		
8600	REHABILITATION CENTERS	45						
8610	REHABILITATION CENTERS & 1 SFR	45	1			1		
8620								
8640	REHABILITATION CENTERS & > 1 SFR & MH(S)	45	4					
9000	PRIVATE ROAD							
9100								
9190								
9200	DITCH CO.							
9230								
9300	DITCHES/WATER STORAGE							
9320								
9380								
9390	DITCHES/WATER STORAGE & MISC IMP	42						
9400	EVAPORATION PONDS							
9490	EVAPORATION PONDS & MISC IMP	42						
9500	LANDSCAPE STRIP							
9600	ASSESSED ON UTILITY ROLL							
9800	INCORPOREAL HEREDETIMENTS							
9900	GOVERNMENT EXEMPT PROPERTIES							
10100	SINGLE FAMILY RESIDENCE		1			1		

Kings County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_flag**
10120	MORE THAN 1 SINGLE FAM RES					1		1
10130	1 SFR & MOBILE HOME		2			1		
10140			1			1		
10160	SINGLE UNIT CONDOMINIUM		1				1	
10170	RESIDENTIAL MH ON PF		1				1	
10190	SFR & MISC IMPROVEMENTS		1			1		
10200	DUPLEX-TWO FAMILY RESIDENCE		2				1	
10210	DUPLEX & 1 SFR		3			1		
10220	DUPLEX & >1 SFR		4			1		
10300	TRIPLEX (3 UNIT)		3				1	
10310	TRIPLEX & 1 SFR		4			1		
10320	TRIPLEX & >1 SFR					1		1
10500	MOBILE HOME		1			1		
10590	MOBILE HOMES & MISC IMPS					1		1
10600	CONDO, PUD OR ZERO LOT LINE		1				1	
10660	COMMON AREA (CONDO OR PUD)							
10700	RESIDENTIAL LOT TO ALT USE	42	1			1		
10710	RES TRANSITIONAL WITH 1 SFR		1			1		
10900	VACANT RESIDENTIAL LOT							
10950	VACANT LOT W/MOBILE HOME		1			1		
10990	RES LOT WITH MISC IMPROVEMENTS		1			1		

Table A-9: Madera County Land Use Crosswalk

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_flag**
AXX								
415								
515								
602								
618								
621								
0AXJ								

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
1027								
2XXX								
38XX	Government, Sec 11, Placeholder, Placeholders							
3AXX	Government, One Dwelling, Placeholder, Placeholders		1			1		
3BXX	Government, 2+ Dwellings, Placeholder, Placeholders					1		1
3CXX	Government, Duplex, Placeholder, Placeholders		2				1	
3MXX	Government, One Mobile Home, Placeholder, Placeholders		1			1		
3XXX	Government, Placeholder, Placeholder, Placeholders							
3XXZ	Government, Placeholder, Placeholder, Unclassifiable							
3ZZZ	Government, Unclassifiable, Unclassifiable, Unclassifiable							
4AXX	Institutional, One Dwelling, Placeholder, Placeholders		1			1		
4AZX	Institutional, One Dwelling, Unclassifiable, Placeholders		1			1		
4AZZ	Institutional, One Dwelling, Unclassifiable, Unclassifiable		1			1		
4BX5	Institutional, 2+ Dwellings, Placeholder, Pool					1		1
4BXX	Institutional, 2+ Dwellings, Placeholder, Placeholders					1		1

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_ flag
4M4X	Institutional, One Mobile Home, Unsec Mo Ho, Placeholders		1			1		
4N5X	Institutional, 2+ Mo Ho, Secured Mo Ho, Placeholders					1		1
4OXX	Institutional, Cabin, Placeholder, Placeholders		1			1		
4P4X	Institutional, Misc, Structure, Unsec Mo Ho, Placeholders		1			1		
4S3X	Institutional, Stand Alone Building, Licensed Mo Ho, Placeholders		1			1		
4S5J	Institutional, Stand Alone Building, Secured Mo Ho, Grazing		1			1		
4X4X	Institutional, Placeholder, Unsec Mo Ho, Placeholders		1			1		
4ZZV	Institutional, Unclassifiable, Unclassifiable, Vacant Land							
4ZZZ	Institutional, Unclassifiable, Unclassifiable, Unclassifiable							
53XX	Utilities, Pipeline Right-of-Way, Placeholder, Placeholders							
5AXX	Utilities, One Dwelling, Placeholder, Placeholders		1			1		
6AXX	Water Company, One Dwelling, Placeholder, Placeholders		1			1		
7XX5	Road, Placeholder, Placeholder, Pool							
7XXV	Road, Placeholder, Placeholder, Vacant Land							

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
7XXX	Road, Placeholder, Placeholder, Placeholders							
7ZZZ	Road, Unclassifiable, Unclassifiable, Unclassifiable							
CASX	Commercial-Sales, One Dwelling, Supermarket, Placeholders	7	1				1	
CASZ	Commercial-Sales, One Dwelling, Supermarket, Unclassifiable	7	1				1	
CXXV	Commercial-Sales, Placeholder, Placeholder, Vacant Land							
CXXX	Commercial-Sales, Placeholder, Placeholder, Placeholders							
CXXZ	Commercial-Sales, Placeholder, Placeholder, Unclassifiable							
CXZZ	Commercial-Sales, Placeholder, Unclassifiable, Unclassifiable							
DAP5	Commercial-Service, One Dwelling, Professional, Pool		1			1		
DAZZ	Commercial-Service, One Dwelling, Unclassifiable, Unclassifiable		1			1		
DB5X	Commercial-Service, 2+ Dwellings, Secured Mo Ho, Placeholders		3			1		
DBBZ	Commercial-Service, 2+ Dwellings, Mini-Storage, Unclassifiable		3			1		
DBHX	Commercial-Service, 2+ Dwellings, Hotel/Motel/Bd&Bkfst, Placeholders		3				1	

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
DBJ4	Commercial-Service, 2+ Dwellings, Medical-Dental, Retail		3			1		
DBKX	Commercial-Service, 2+ Dwellings, Mobilehome Park, Placeholders		3			1		
DBXZ	Commercial-Service, 2+ Dwellings, Placeholder, Unclassifiable		3			1		
DBZZ	Commercial-Service, 2+ Dwellings, Unclassifiable, Unclassifiable		3			1		
DEHX	Commercial-Service, Fourplex, Hotel/Motel/Bd&Bkfst, Placeholders						1	1
DEJX	Commercial-Service, Fourplex, Medical-Dental, Placeholders						1	1
DGHX	Commercial-Service, 16+ Units, Hotel/Motel/Bd&Bkfst, Placeholders						1	1
DMR4	Commercial-Service, One Mobile Home, Restaurant/Cafe/Bar, Retail		1			1		
DN5Z	Commercial-Service, 2+ Mo Ho, Secured Mo Ho, Unclassifiable		2			1		
DNAX	Commercial-Service, 2+ Mo Ho, Auto Related, Placeholders		2			1		
DNKX	Commercial-Service, 2+ Mo Ho, Mobilehome Park, Placeholders		2			1		
DXXV	Commercial-Service, Placeholder, Placeholder, Vacant Land							

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
DXXX	Commercial-Service, Placeholder, Placeholder, Placeholders							
DZZZ	Commercial-Service, Unclassifiable, Unclassifiable, Unclassifiable							
EAXX	Commercial-Rec, One Dwelling, Placeholder, Placeholders		1			1		
EGXX	Commercial-Rec, 16+ Units, Placeholder, Placeholders						1	1
EPKX	Commercial-Rec, Misc, Structure, Mobilehome Park, Placeholders					1		1
GBKX	Commercial-Other, 2+ Dwellings, Mobilehome Park, Placeholders		2			1		
GBXX	Commercial-Other, 2+ Dwellings, Placeholder, Placeholders		2			1		
GGXX	Commercial-Other, 16+ Units, Placeholder, Placeholders						1	1
GN5X	Commercial-Other, 2+ Mo Ho, Secured Mo Ho, Placeholders		2			1		
GNKX	Commercial-Other, 2+ Mo Ho, Mobilehome Park, Placeholders		2			1		
GPKX	Commercial-Other, Misc, Structure, Mobilehome Park, Placeholders							
GPXV	Commercial-Other, Misc, Structure, Placeholder, Vacant Land							
GPZV	Commercial-Other, Misc, Structure, Unclassifiable, Vacant Land							

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
GXKX	Commercial-Other, Placeholder, Mobilehome Park, Placeholders					1		1
GXXV	Commercial-Other, Placeholder, Placeholder, Vacant Land							
IMXX	Industrial-Manufacture, One Mobile Home, Placeholder, Placeholders		1			1		
KAXX	Industrial-Other, One Dwelling, Placeholder, Placeholders		1			1		
KXXV	Industrial-Other, Placeholder, Placeholder, Vacant Land							
PXXV	Ag Preserve, Placeholder, Placeholder, Vacant Land							
RA3X	Res-SFD-Detached, One Dwelling, Licensed Mo Ho, Placeholders		1			1		
RA5X	Res-SFD-Detached, One Dwelling, Secured Mo Ho, Placeholders		1			1		
RAKX	Res-SFD-Detached, One Dwelling, Mobilehome Park, Placeholders		1			1		
RAX%			1			1		
RAX5	Res-SFD-Detached, One Dwelling, Placeholder, Pool		1			1		
RAXV	Res-SFD-Detached, One Dwelling, Placeholder, Vacant Land							
RAXX	Res-SFD-Detached, One Dwelling, Placeholder, Placeholders		1			1		

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
RAXZ	Res-SFD-Detached, One Dwelling, Placeholder, Unclassifiable		1			1		
RAZX	Res-SFD-Detached, One Dwelling, Unclassifiable, Placeholders		1			1		
RB35	Res-SFD-Detached, 2+ Dwellings, Licensed Mo Ho, Pool		2			1		
RB3X	Res-SFD-Detached, 2+ Dwellings, Licensed Mo Ho, Placeholders		2			1		
RB45	Res-SFD-Detached, 2+ Dwellings, Unsec Mo Ho, Pool		2			1		
RB4X	Res-SFD-Detached, 2+ Dwellings, Unsec Mo Ho, Placeholders		2			1		
RB55	Res-SFD-Detached, 2+ Dwellings, Secured Mo Ho, Pool		2			1		
RB56	Res-SFD-Detached, 2+ Dwellings, Secured Mo Ho, Permanent Foundation		2			1		
RB5X	Res-SFD-Detached, 2+ Dwellings, Secured Mo Ho, Placeholders		2			1		
RBX5	Res-SFD-Detached, 2+ Dwellings, Placeholder, Pool		2			1		
RBX6	Res-SFD-Detached, 2+ Dwellings, Placeholder, Permanent Foundation		2			1		
RBXX	Res-SFD-Detached, 2+ Dwellings, Placeholder, Placeholders		2			1		
RBZ5	Res-SFD-Detached, 2+ Dwellings, Unclassifiable, Pool		2			1		
RBZX	Res-SFD-Detached, 2+ Dwellings, Unclassifiable, Placeholders		2			1		

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_ flag
RCXX	Res-SFD-Detached, Duplex, Placeholder, Placeholders		2				1	
RDXX	Res-SFD-Detached, Triplex, Placeholder, Placeholders		3				1	
REXX	Res-SFD-Detached, Fourplex, Placeholder, Placeholders		4				1	
RFXX	Res-SFD-Detached, 5-15 Units, Placeholder, Placeholders						1	1
RGX5	Res-SFD-Detached, 16+ Units, Placeholder, Pool						1	1
RM36	Res-SFD-Detached, One Mobile Home, Licensed Mo Ho, Permanent Foundation		1			1		
RM3X	Res-SFD-Detached, One Mobile Home, Licensed Mo Ho, Placeholders		1			1		
RM4X	Res-SFD-Detached, One Mobile Home, Unsec Mo Ho, Placeholders		1			1		
RM56	Res-SFD-Detached, One Mobile Home, Secured Mo Ho, Permanent Foundation		1			1		
RM5X	Res-SFD-Detached, One Mobile Home, Secured Mo Ho, Placeholders		1			1		
RMX5	Res-SFD-Detached, One Mobile Home, Placeholder, Pool		1			1		
RMX6	Res-SFD-Detached, One Mobile Home, Placeholder, Permanent Foundation		1			1		
RMXX	Res-SFD-Detached, One Mobile Home, Placeholder, Placeholders		1			1		

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
RN3X	Res-SFD-Detached, 2+ Mo Ho, Licensed Mo Ho, Placeholders		2			1		
RN4X	Res-SFD-Detached, 2+ Mo Ho, Unsec Mo Ho, Placeholders		2			1		
RN55	Res-SFD-Detached, 2+ Mo Ho, Secured Mo Ho, Pool		2			1		
RN56	Res-SFD-Detached, 2+ Mo Ho, Secured Mo Ho, Permanent Foundation		2			1		
RN5V	Res-SFD-Detached, 2+ Mo Ho, Secured Mo Ho, Vacant Land							
RN5X	Res-SFD-Detached, 2+ Mo Ho, Secured Mo Ho, Placeholders		2			1		
RNXX	Res-SFD-Detached, 2+ Mo Ho, Placeholder, Placeholders		2			1		
RNZX	Res-SFD-Detached, 2+ Mo Ho, Unclassifiable, Placeholders		2			1		
ROXX	Res-SFD-Detached, Cabin, Placeholder, Placeholders		1			1		
RP3X	Res-SFD-Detached, Misc, Structure, Licensed Mo Ho, Placeholders		1			1		
RPX5	Res-SFD-Detached, Misc, Structure, Placeholder, Pool		1			1		
RPXV	Res-SFD-Detached, Misc, Structure, Placeholder, Vacant Land					1		
RPXX	Res-SFD-Detached, Misc, Structure, Placeholder, Placeholders		1			1		
RPXZ	Res-SFD-Detached, Misc, Structure, Placeholder, Unclassifiable					1		

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_flag**
RRXX	Res-SFD-Detached, , Placeholder, Placeholders					1		
RSXX	Res-SFD-Detached, Stand Alone Building, Placeholder, Placeholders		1			1		
RTXX	Res-SFD-Detached, Strip Development, Placeholder, Placeholders		1			1		
RXX5	Res-SFD-Detached, Placeholder, Placeholder, Pool		1			1		
RXX6	Res-SFD-Detached, Placeholder, Placeholder, Permanent Foundation		1			1		
RXXV	Res-SFD-Detached, Placeholder, Placeholder, Vacant Land							
RXXX	Res-SFD-Detached, Placeholder, Placeholder, Placeholders		1			1		
RXXZ	Res-SFD-Detached, Placeholder, Placeholder, Unclassifiable		1			1		
RXYX	Res-SFD-Detached, Placeholder, Cotton Gin, Placeholders		1			1		
RZXV	Res-SFD-Detached, Unclassifiable, Placeholder, Vacant Land							
RZXX	Res-SFD-Detached, Unclassifiable, Placeholder, Placeholders		1			1		
SAX5	Res-SFD-0 Lot Line, One Dwelling, Placeholder, Pool		1				1	

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
SAXX	Res-SFD-0 Lot Line, One Dwelling, Placeholder, Placeholders		1				1	
SOXX	Res-SFD-0 Lot Line, Cabin, Placeholder, Placeholders		1				1	
SXXV	Res-SFD-0 Lot Line, Placeholder, Placeholder, Vacant Land							
TAXX	Res-Multi-Fam-Apartmt, One Dwelling, Placeholder, Placeholders		1				1	
TBXX	Res-Multi-Fam-Apartmt, 2+ Dwellings, Placeholder, Placeholders		2				1	
TCXX	Res-Multi-Fam-Apartmt, Duplex, Placeholder, Placeholders		2				1	
TDXX	Res-Multi-Fam-Apartmt, Triplex, Placeholder, Placeholders		3				1	
TEX5	Res-Multi-Fam-Apartmt, Fourplex, Placeholder, Pool		4				1	
TEXX	Res-Multi-Fam-Apartmt, Fourplex, Placeholder, Placeholders		4				1	
TFX5	Res-Multi-Fam-Apartmt, 5-15 Units, Placeholder, Pool						1	1
TFXX	Res-Multi-Fam-Apartmt, 5-15 Units, Placeholder, Placeholders						1	1
TFZ5	Res-Multi-Fam-Apartmt, 5-15 Units, Unclassifiable, Pool						1	1
TGX5	Res-Multi-Fam-Apartmt, 16+ Units, Placeholder, Pool						1	1

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
TGXV	Res-Multi-Fam-Apartmt, 16+ Units, Placeholder, Vacant Land							1
TGXX	Res-Multi-Fam-Apartmt, 16+ Units, Placeholder, Placeholders						1	1
TXXV	Res-Multi-Fam-Apartmt, Placeholder, Placeholder, Vacant Land							
TXXX	Res-Multi-Fam-Apartmt, Placeholder, Placeholder, Placeholders							
UAX5	Res-Multi-Condo, One Dwelling, Placeholder, Pool		1				1	
UAXX	Res-Multi-Condo, One Dwelling, Placeholder, Placeholders		1				1	
UBXX	Res-Multi-Condo, 2+ Dwellings, Placeholder, Placeholders		2				1	
UCXX	Res-Multi-Condo, Duplex, Placeholder, Placeholders		2				1	
UE5X	Res-Multi-Condo, Fourplex, Secured Mo Ho, Placeholders		4				1	
UEXX	Res-Multi-Condo, Fourplex, Placeholder, Placeholders		3				1	
UGXX	Res-Multi-Condo, 16+ Units, Placeholder, Placeholders						1	1
UPXX	Res-Multi-Condo, Misc, Structure, Placeholder, Placeholders		1				1	
UXX5	Res-Multi-Condo, Placeholder, Placeholder, Pool		1				1	

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
UXXV	Res-Multi-Condo, Placeholder, Placeholder, Vacant Land							
UXXX	Res-Multi-Condo, Placeholder, Placeholder, Placeholders		1				1	
UZX5	Res-Multi-Condo, Unclassifiable, Placeholder, Pool		1				1	
UZXX	Res-Multi-Condo, Unclassifiable, Placeholder, Placeholders		1				1	
VAXX	Res-Other, One Dwelling, Placeholder, Placeholders		1			1		
VB5X	Res-Other, 2+ Dwellings, Secured Mo Ho, Placeholders		2			1		
VBXX	Res-Other, 2+ Dwellings, Placeholder, Placeholders		2			1		
VGIX	Res-Other, 16+ Units, Farm Labor Camp, Placeholders						1	1
VGIZ	Res-Other, 16+ Units, Farm Labor Camp, Unclassifiable						1	1
VGX5	Res-Other, 16+ Units, Placeholder, Pool						1	1
VGXX	Res-Other, 16+ Units, Placeholder, Placeholders						1	1
VNKX	Res-Other, 2+ Mo Ho, Mobilehome Park, Placeholders					1		1
VNKZ	Res-Other, 2+ Mo Ho, Mobilehome Park, Unclassifiable					1		1
VPHX	Res-Other, Misc, Structure, Hotel/Motel/Bd&Bkfst, Placeholders						1	1

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_flag**
VPX5	Res-Other, Misc, Structure, Placeholder, Pool		1			1		
VPXX	Res-Other, Misc, Structure, Placeholder, Placeholders		1			1		
VSXX	Res-Other, Stand Alone Building, Placeholder, Placeholders		1			1		
VXK5	Res-Other, Placeholder, Mobilehome Park, Pool		1			1		
VXXV	Res-Other, Placeholder, Placeholder, Vacant Land		1			1		
VXXX	Res-Other, Placeholder, Placeholder, Placeholders		1			1		
VZZV	Res-Other, Unclassifiable, Unclassifiable, Vacant Land		1			1		
VZZZ	Res-Other, Unclassifiable, Unclassifiable, Unclassifiable		1			1		
WOXX	Recreational, Cabin, Placeholder, Placeholders		1			1		
WXXV	Recreational, Placeholder, Placeholder, Vacant Land							
ZBXX	Unclassifiable, 2+ Dwellings, Placeholder, Placeholders		2			1		
ZM3X	Unclassifiable, One Mobile Home, Licensed Mo Ho, Placeholders		1			1		
ZPXX	Unclassifiable, Misc, Structure, Placeholder, Placeholders							

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
ZSXX	Unclassifiable, Stand Alone Building, Placeholder, Placeholders							
ZXXV	Unclassifiable, Placeholder, Placeholder, Vacant Land							
ZXXX	Unclassifiable, Placeholder, Placeholder, Placeholders							
ZZZV	Unclassifiable, Unclassifiable, Unclassifiable, Vacant Land							
4B3X						1		1
4B5X						1		1
4S5X			1			1		
R0XX			1			1		
rAXX			1			1		
raxx			1			1		
RGKX						1		1
RM33			1			1		
RNKX						1		1
RNX6						1		1
rxxv			1			1		
SCL4			2				1	
UX5X							1	1
UXYX							1	1
VM3X			1			1		
0XXV								
3ZZV								
AXX5								
CAX5								
CPZZ								
CRXV								
DAX5								
GXVV								

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_ flag
GZXV								
GZZV								
KPXV								
KPXX								
SIZZ								
SUXX								
VXX5								
VXXZ								
XXV								
ZXXZ								
ZZZZ								
DM3X		0						
4ZXX								
3PXX	Government, Misc, Structure, Placeholder, Placeholders	42						
3SPZ	Government, Stand Alone Building, Professional, Unclassifiable	31						
3SXX	Government, Stand Alone Building, Placeholder, Placeholders	42						
3XXJ	Government, Placeholder, Placeholder, Grazing	42						
3XXV	Government, Placeholder, Placeholder, Vacant Land	42						
4LXX	Institutional, Lodging, Placeholder, Placeholders	38					1	
4PH3	Institutional, Misc, Structure, Hotel/Motel/Bd&Bkfst, Wholesale	38					1	1
4PJ4	Institutional, Misc, Structure, Medical-Dental, Retail	32						

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
4PXX	Institutional, Misc, Structure, Placeholder, Placeholders	45						
4PXZ	Institutional, Misc, Structure, Placeholder, Unclassifiable	45						
4PZZ	Institutional, Misc, Structure, Unclassifiable, Unclassifiable	45						
4SJX	Institutional, Stand Alone Building, Medical-Dental, Placeholders	32						
4SXX	Institutional, Stand Alone Building, Placeholder, Placeholders	45						
4SZZ	Institutional, Stand Alone Building, Unclassifiable, Unclassifiable	45						
4XXV	Institutional, Placeholder, Placeholder, Vacant Land	42						
4XXX	Institutional, Placeholder, Placeholder, Placeholders	45						
5IZZ	Utilities, Industrial Park, Unclassifiable, Unclassifiable	34						
5PXX	Utilities, Misc, Structure, Placeholder, Placeholders	42						
5SXX	Utilities, Stand Alone Building, Placeholder, Placeholders	34						
5XXV	Utilities, Placeholder, Placeholder, Vacant Land	42						
5XXX	Utilities, Placeholder, Placeholder, Placeholders	42						

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_ flag
5XXY	Utilities, Placeholder, Placeholder, Nectarines	42						
6PXX	Water Company, Misc, Structure, Placeholder, Placeholders	34						
6SXX	Water Company, Stand Alone Building, Placeholder, Placeholders	42						
6XXV	Water Company, Placeholder, Placeholder, Vacant Land	42						
6XXX	Water Company, Placeholder, Placeholder, Placeholders	42						
6XXZ	Water Company, Placeholder, Placeholder, Unclassifiable	42						
6ZXX	Water Company, Unclassifiable, Placeholder, Placeholders	42						
6ZZZ	Water Company, Unclassifiable, Unclassifiable, Unclassifiable	42						
9PLX	Timber, Misc, Structure, Lumber, Placeholders	42						
9XLX	Timber, Placeholder, Lumber, Placeholders	42						
9XXV	Timber, Placeholder, Placeholder, Vacant Land	42						
9XXX	Timber, Placeholder, Placeholder, Placeholders	42						
AA3G	Agricultural, One Dwelling, Licensed Mo Ho, Grapes	42	1			1		
AA3J	Agricultural, One Dwelling, Licensed Mo Ho, Grazing	42	1			1		

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_ flag
AA3X	Agricultural, One Dwelling, Licensed Mo Ho, Placeholders	42	1			1		
AA8G	Agricultural, One Dwelling, Cons Esmnt Subvened, Grapes	42	1			1		
AA8R	Agricultural, One Dwelling, Cons Esmnt Subvened, Row Crop	42	1			1		
AAFG	Agricultural, One Dwelling, Food Processing, Grapes	42	1			1		
AAIG	Agricultural, One Dwelling, Farm Labor Camp, Grapes	42				1		1
AANU	Agricultural, One Dwelling, Nursery/Flower/GrHs, Commercial Poultry	42	1			1		
AANV	Agricultural, One Dwelling, Nursery/Flower/GrHs, Vacant Land	42	1			1		
AAWJ	Agricultural, One Dwelling, Winery, Grazing	42	1			1		
AAX5	Agricultural, One Dwelling, Placeholder, Pool	42	1			1		
AAXA	Agricultural, One Dwelling, Placeholder, Almonds	42	1			1		
AAXC	Agricultural, One Dwelling, Placeholder, Citrus	42	1			1		
AAXD	Agricultural, One Dwelling, Placeholder, Dry Farm	42	1			1		
AAXE	Agricultural, One Dwelling, Placeholder, Dairy	42	1			1		
AAXG	Agricultural, One Dwelling, Placeholder, Grapes	42	1			1		
AAXI	Agricultural, One Dwelling, Placeholder, Irrigated Pasture	42	1			1		

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
AAXJ	Agricultural, One Dwelling, Placeholder, Grazing	42	1			1		
AAXN	Agricultural, One Dwelling, Placeholder, Apples	42	1			1		
AAXP	Agricultural, One Dwelling, Placeholder, Pistachios	42	1			1		
AAXR	Agricultural, One Dwelling, Placeholder, Row Crop	42	1			1		
AAXT	Agricultural, One Dwelling, Placeholder, Commercial Animal	42	1			1		
AAXU	Agricultural, One Dwelling, Placeholder, Commercial Poultry	42	1			1		
AAXV	Agricultural, One Dwelling, Placeholder, Vacant Land	42	1			1		
AAXW	Agricultural, One Dwelling, Placeholder, Walnuts	42	1			1		
AAXX	Agricultural, One Dwelling, Placeholder, Placeholders	42	1			1		
AAXY	Agricultural, One Dwelling, Placeholder, Nectarines	42	1			1		
AAXZ	Agricultural, One Dwelling, Placeholder, Unclassifiable	42	1			1		
AB35	Agricultural, 2+ Dwellings, Licensed Mo Ho, Pool	42	3			1		
AB3A	Agricultural, 2+ Dwellings, Licensed Mo Ho, Almonds	42	3			1		
AB3G	Agricultural, 2+ Dwellings, Licensed Mo Ho, Grapes	42	3			1		
AB3I	Agricultural, 2+ Dwellings, Licensed Mo Ho, Irrigated Pasture	42	3			1		

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_ flag
AB3J	Agricultural, 2+ Dwellings, Licensed Mo Ho, Grazing	42	3			1		
AB3R	Agricultural, 2+ Dwellings, Licensed Mo Ho, Row Crop	42	3			1		
AB3U	Agricultural, 2+ Dwellings, Licensed Mo Ho, Commercial Poultry	42	3			1		
AB3X	Agricultural, 2+ Dwellings, Licensed Mo Ho, Placeholders	42	3			1		
AB3Z	Agricultural, 2+ Dwellings, Licensed Mo Ho, Unclassifiable	42	3			1		
AB45	Agricultural, 2+ Dwellings, Unsec Mo Ho, Pool	42	3			1		
AB46	Agricultural, 2+ Dwellings, Unsec Mo Ho, Permanent Foundation	42	3			1		
AB4A	Agricultural, 2+ Dwellings, Unsec Mo Ho, Almonds	42	3			1		
AB4E	Agricultural, 2+ Dwellings, Unsec Mo Ho, Dairy	42	3			1		
AB4G	Agricultural, 2+ Dwellings, Unsec Mo Ho, Grapes	42	3			1		
AB4J	Agricultural, 2+ Dwellings, Unsec Mo Ho, Grazing	42	3			1		
AB4R	Agricultural, 2+ Dwellings, Unsec Mo Ho, Row Crop	42	3			1		
AB4X	Agricultural, 2+ Dwellings, Unsec Mo Ho, Placeholders	42	3			1		
AB55	Agricultural, 2+ Dwellings, Secured Mo Ho, Pool	42	3			1		

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
AB56	Agricultural, 2+ Dwellings, Secured Mo Ho, Permanent Foundation	42	3			1		
AB5A	Agricultural, 2+ Dwellings, Secured Mo Ho, Almonds	42	3			1		
AB5E	Agricultural, 2+ Dwellings, Secured Mo Ho, Dairy	42	3			1		
AB5G	Agricultural, 2+ Dwellings, Secured Mo Ho, Grapes	42	3			1		
AB5I	Agricultural, 2+ Dwellings, Secured Mo Ho, Irrigated Pasture	42	3			1		
AB5J	Agricultural, 2+ Dwellings, Secured Mo Ho, Grazing	42	3			1		
AB5O	Agricultural, 2+ Dwellings, Secured Mo Ho, Olives	42	3			1		
AB5R	Agricultural, 2+ Dwellings, Secured Mo Ho, Row Crop	42	3			1		
AB5T	Agricultural, 2+ Dwellings, Secured Mo Ho, Commercial Animal	42	3			1		
AB5U	Agricultural, 2+ Dwellings, Secured Mo Ho, Commercial Poultry	42	3			1		
AB5W	Agricultural, 2+ Dwellings, Secured Mo Ho, Walnuts	42	3			1		
AB5X	Agricultural, 2+ Dwellings, Secured Mo Ho, Placeholders	42	3			1		
AB8G	Agricultural, 2+ Dwellings, Cons Esmnt Subvened, Grapes	42	3			1		
ABCG	Agricultural, 2+ Dwellings, Convenience Store, Grapes	42	3			1		

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_ flag
ABIX	Agricultural, 2+ Dwellings, Farm Labor Camp, Placeholders	42	3			1		
ABX5	Agricultural, 2+ Dwellings, Placeholder, Pool	42	3			1		
ABXA	Agricultural, 2+ Dwellings, Placeholder, Almonds	42	3			1		
ABXC	Agricultural, 2+ Dwellings, Placeholder, Citrus	42	3			1		
ABXD	Agricultural, 2+ Dwellings, Placeholder, Dry Farm	42	3			1		
ABXE	Agricultural, 2+ Dwellings, Placeholder, Dairy	42	3			1		
ABXF	Agricultural, 2+ Dwellings, Placeholder, Figs	42	3			1		
ABXG	Agricultural, 2+ Dwellings, Placeholder, Grapes	42	3			1		
ABXI	Agricultural, 2+ Dwellings, Placeholder, Irrigated Pasture	42	3			1		
ABXJ	Agricultural, 2+ Dwellings, Placeholder, Grazing	42	3			1		
ABXO	Agricultural, 2+ Dwellings, Placeholder, Olives	42	3			1		
ABXP	Agricultural, 2+ Dwellings, Placeholder, Pistachios	42	3			1		
ABXR	Agricultural, 2+ Dwellings, Placeholder, Row Crop	42	3			1		
ABXS	Agricultural, 2+ Dwellings, Placeholder, Pomegranates	42	3			1		
ABXV	Agricultural, 2+ Dwellings, Placeholder, Vacant Land	42	3			1		

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_ flag
ABXW	Agricultural, 2+ Dwellings, Placeholder, Walnuts	42	3			1		
ABXX	Agricultural, 2+ Dwellings, Placeholder, Placeholders	42	3			1		
ABXZ	Agricultural, 2+ Dwellings, Placeholder, Unclassifiable	42	3			1		
ACXG	Agricultural, Duplex, Placeholder, Grapes	42					1	1
GBBX		36						
ADIG	Agricultural, Triplex, Farm Labor Camp, Grapes	42					1	1
AM35	Agricultural, One Mobile Home, Licensed Mo Ho, Pool	42	1			1		
AM3A	Agricultural, One Mobile Home, Licensed Mo Ho, Almonds	42	1			1		
AM3C	Agricultural, One Mobile Home, Licensed Mo Ho, Citrus	42	1			1		
AM3G	Agricultural, One Mobile Home, Licensed Mo Ho, Grapes	42	1			1		
AM3H	Agricultural, One Mobile Home, Licensed Mo Ho, Grain	42	1			1		
AM3J	Agricultural, One Mobile Home, Licensed Mo Ho, Grazing	42	1			1		
AM3R	Agricultural, One Mobile Home, Licensed Mo Ho, Row Crop	42	1			1		
AM3U	Agricultural, One Mobile Home, Licensed Mo Ho, Commercial Poultry	42	1			1		

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
AM3X	Agricultural, One Mobile Home, Licensed Mo Ho, Placeholders	42	1			1		
AM4A	Agricultural, One Mobile Home, Unsec Mo Ho, Almonds	42	1			1		
AM4J	Agricultural, One Mobile Home, Unsec Mo Ho, Grazing	42	1			1		
AM4P	Agricultural, One Mobile Home, Unsec Mo Ho, Pistachios	42	1			1		
AM4R	Agricultural, One Mobile Home, Unsec Mo Ho, Row Crop	42	1			1		
AM4X	Agricultural, One Mobile Home, Unsec Mo Ho, Placeholders	42	1			1		
AM4Z	Agricultural, One Mobile Home, Unsec Mo Ho, Unclassifiable	42	1			1		
AM56	Agricultural, One Mobile Home, Secured Mo Ho, Permanent Foundation	42	1			1		
AM5A	Agricultural, One Mobile Home, Secured Mo Ho, Almonds	42	1			1		
AM5C	Agricultural, One Mobile Home, Secured Mo Ho, Citrus	42	1			1		
AM5G	Agricultural, One Mobile Home, Secured Mo Ho, Grapes	42	1			1		
AM5I	Agricultural, One Mobile Home, Secured Mo Ho, Irrigated Pasture	42	1			1		
AM5J	Agricultural, One Mobile Home, Secured Mo Ho, Grazing	42	1			1		
AM5P	Agricultural, One Mobile Home, Secured Mo Ho, Pistachios	42	1			1		

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
AM5Q	Agricultural, One Mobile Home, Secured Mo Ho, Peaches	42	1			1		
AM5R	Agricultural, One Mobile Home, Secured Mo Ho, Row Crop	42	1			1		
AM5S	Agricultural, One Mobile Home, Secured Mo Ho, Pomegranates	42	1			1		
AM5U	Agricultural, One Mobile Home, Secured Mo Ho, Commercial Poultry	42	1			1		
AM5X	Agricultural, One Mobile Home, Secured Mo Ho, Placeholders	42	1			1		
AM5Z	Agricultural, One Mobile Home, Secured Mo Ho, Unclassifiable	42	1			1		
AMX6	Agricultural, One Mobile Home, Placeholder, Permanent Foundation	42	1			1		
AMXA	Agricultural, One Mobile Home, Placeholder, Almonds	42	1			1		
AMXG	Agricultural, One Mobile Home, Placeholder, Grapes	42	1			1		
AB4Z		42	2			1		
AMXJ	Agricultural, One Mobile Home, Placeholder, Grazing	42	1			1		
AMXS	Agricultural, One Mobile Home, Placeholder, Pomegranates	42	1			1		
AMXX	Agricultural, One Mobile Home, Placeholder, Placeholders	42	1			1		
AN3G	Agricultural, 2+ Mo Ho, Licensed Mo Ho, Grapes	42	3			1		
AN3J	Agricultural, 2+ Mo Ho, Licensed Mo Ho, Grazing	42	3			1		

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
AN3P	Agricultural, 2+ Mo Ho, Licensed Mo Ho, Pistachios	42	3			1		
AN3Z	Agricultural, 2+ Mo Ho, Licensed Mo Ho, Unclassifiable	42	3			1		
AN56	Agricultural, 2+ Mo Ho, Secured Mo Ho, Permanent Foundation	42	3			1		
AN5A	Agricultural, 2+ Mo Ho, Secured Mo Ho, Almonds	42	3			1		
AN5J	Agricultural, 2+ Mo Ho, Secured Mo Ho, Grazing	42	3			1		
AN5R	Agricultural, 2+ Mo Ho, Secured Mo Ho, Row Crop	42	3			1		
AN5X	Agricultural, 2+ Mo Ho, Secured Mo Ho, Placeholders	42	3			1		
ANEP	Agricultural, 2+ Mo Ho, Farm Mach & Prod, Pistachios	42	3			1		
ANXG	Agricultural, 2+ Mo Ho, Placeholder, Grapes	42	3			1		
ANXJ	Agricultural, 2+ Mo Ho, Placeholder, Grazing	42	3			1		
AOXJ	Agricultural, Cabin, Placeholder, Grazing	42	1			1		
AOXX	Agricultural, Cabin, Placeholder, Placeholders	42	1			1		
APNX	Agricultural, Misc, Structure, Nursery/Flower/GrHs, Placeholders	42						
APXC	Agricultural, Misc, Structure, Placeholder, Citrus	42						
APXJ	Agricultural, Misc, Structure, Placeholder, Grazing	42						
APXX	Agricultural, Misc, Structure, Placeholder, Placeholders	42						

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
APZA	Agricultural, Misc, Structure, Unclassifiable, Almonds	42						
AQXA	Agricultural, Ag Office, Placeholder, Almonds	42						
AQXX	Agricultural, Ag Office, Placeholder, Placeholders	42						
ARXG	Agricultural, , Placeholder, Grapes	42						
ARXJ	Agricultural, , Placeholder, Grazing	42						
ASXA	Agricultural, Stand Alone Building, Placeholder, Almonds	42						
ASXG	Agricultural, Stand Alone Building, Placeholder, Grapes	42						
ASXX	Agricultural, Stand Alone Building, Placeholder, Placeholders	42						
ASXZ	Agricultural, Stand Alone Building, Placeholder, Unclassifiable	42						
AX8G	Agricultural, Placeholder, Cons Esmnt Subvened, Grapes	42						
AX8R	Agricultural, Placeholder, Cons Esmnt Subvened, Row Crop	42						
AXVW	Agricultural, Placeholder, Warehouse, Walnuts	42						
AxX5	Agricultural, Placeholder, Placeholder, Pool	42						
AXX8	Agricultural, Placeholder, Placeholder, Prunes	42						
AXXA	Agricultural, Placeholder, Placeholder, Almonds	42						

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
AXXC	Agricultural, Placeholder, Placeholder, Citrus	42						
AXXD	Agricultural, Placeholder, Placeholder, Dry Farm	42						
AXXE	Agricultural, Placeholder, Placeholder, Dairy	42						
AXXF	Agricultural, Placeholder, Placeholder, Figs	42						
AXXG	Agricultural, Placeholder, Placeholder, Grapes	42						
AXXI	Agricultural, Placeholder, Placeholder, Irrigated Pasture	42						
AXXJ	Agricultural, Placeholder, Placeholder, Grazing	42						
AXXK	Agricultural, Placeholder, Placeholder, Kiwi	42						
AXXL	Agricultural, Placeholder, Placeholder, Plums	42						
AXXN	Agricultural, Placeholder, Placeholder, Apples	42						
AXXO	Agricultural, Placeholder, Placeholder, Olives	42						
AXXP	Agricultural, Placeholder, Placeholder, Pistachios	42						
GVZX		41						
AXXQ	Agricultural, Placeholder, Placeholder, Peaches	42						
AXXR	Agricultural, Placeholder, Placeholder, Row Crop	42						

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
AXXS	Agricultural, Placeholder, Placeholder, Pomegranates	42						
AXXT	Agricultural, Placeholder, Placeholder, Commercial Animal	42						
AXXU	Agricultural, Placeholder, Placeholder, Commercial Poultry	42						
AXXV	Agricultural, Placeholder, Placeholder, Vacant Land	42						
AXXW	Agricultural, Placeholder, Placeholder, Walnuts	42						
AXXX	Agricultural, Placeholder, Placeholder, Placeholders	42						
AXXZ	Agricultural, Placeholder, Placeholder, Unclassifiable	42						
AZXD	Agricultural, Unclassifiable, Placeholder, Dry Farm	42						
AZZZ	Agricultural, Unclassifiable, Unclassifiable, Unclassifiable	42						
BAFG	Ag-Ind/Comm/Mfg, One Dwelling, Food Processing, Grapes	34	1			1		
BAXT	Ag-Ind/Comm/Mfg, One Dwelling, Placeholder, Commercial Animal	42	1			1		
BAXX	Ag-Ind/Comm/Mfg, One Dwelling, Placeholder, Placeholders	42	1			1		

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
BIFZ	Ag-Ind/Comm/Mfg, Industrial Park, Food Processing, Unclassifiable	34						
BM5T	Ag-Ind/Comm/Mfg, One Mobile Home, Secured Mo Ho, Commercial Animal	42	1			1		
BMYX	Ag-Ind/Comm/Mfg, One Mobile Home, Cotton Gin, Placeholders	42	1			1		
BN5Z	Ag-Ind/Comm/Mfg, 2+ Mo Ho, Secured Mo Ho, Unclassifiable	42	3			1		
BPEZ	Ag-Ind/Comm/Mfg, Misc, Structure, Farm Mach & Prod, Unclassifiable	42						
BPFA	Ag-Ind/Comm/Mfg, Misc, Structure, Food Processing, Almonds	42						
BPFX	Ag-Ind/Comm/Mfg, Misc, Structure, Food Processing, Placeholders	42						
BPFZ	Ag-Ind/Comm/Mfg, Misc, Structure, Food Processing, Unclassifiable	42						
BPXX	Ag-Ind/Comm/Mfg, Misc, Structure, Placeholder, Placeholders	42						
BPYG	Ag-Ind/Comm/Mfg, Misc, Structure, Cotton Gin, Grapes	42						
BPYX	Ag-Ind/Comm/Mfg, Misc, Structure, Cotton Gin, Placeholders	42						
BQVH	Ag-Ind/Comm/Mfg, Ag Office, Warehouse, Grain	34						
BQYX	Ag-Ind/Comm/Mfg, Ag Office, Cotton Gin, Placeholders	34						

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
BSVX	Ag-Ind/Comm/Mfg, Stand Alone Building, Warehouse, Placeholders	36						
BSWX	Ag-Ind/Comm/Mfg, Stand Alone Building, Winery, Placeholders	34						
BSXX	Ag-Ind/Comm/Mfg, Stand Alone Building, Placeholder, Placeholders	34						
BXE4	Ag-Ind/Comm/Mfg, Placeholder, Farm Mach & Prod, Retail	34						
BXEZ	Ag-Ind/Comm/Mfg, Placeholder, Farm Mach & Prod, Unclassifiable	34						
BXFA	Ag-Ind/Comm/Mfg, Placeholder, Food Processing, Almonds	34						
BXFX	Ag-Ind/Comm/Mfg, Placeholder, Food Processing, Placeholders	34						
BXXA	Ag-Ind/Comm/Mfg, Placeholder, Placeholder, Almonds	42						
BXXX	Ag-Ind/Comm/Mfg, Placeholder, Placeholder, Placeholders	42						
CAAX	Commercial-Sales, One Dwelling, Auto Related, Placeholders	41	1			1		
CAC4	Commercial-Sales, One Dwelling, Convenience Store, Retail	41	1			1		
CAEX	Commercial-Sales, One Dwelling, Farm Mach & Prod, Placeholders	41	1			1		
CAF4	Commercial-Sales, One Dwelling, Food Processing, Retail	41	1			1		

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_ flag
CAHX	Commercial-Sales, One Dwelling, Hotel/Motel/Bd&Bkfst, Placeholders	38					1	1
CAMX	Commercial-Sales, One Dwelling, Market, Placeholders	41	1			1		
CAN4	Commercial-Sales, One Dwelling, Nursery/Flower/GrHs, Retail	41	1			1		
CAPX	Commercial-Sales, One Dwelling, Professional, Placeholders	41	1			1		
CARX	Commercial-Sales, One Dwelling, Restaurant/Cafe/Bar, Placeholders	41	1			1		
CATX	Commercial-Sales, One Dwelling, Trucking, Placeholders	41	1			1		
CAVX	Commercial-Sales, One Dwelling, Warehouse, Placeholders	36	1			1		
CAX3	Commercial-Sales, One Dwelling, Placeholder, Wholesale	41	1			1		
CAXX	Commercial-Sales, One Dwelling, Placeholder, Placeholders	41	1			1		
CB5X	Commercial-Sales, 2+ Dwellings, Secured Mo Ho, Placeholders	41	3			1		
CBG4	Commercial-Sales, 2+ Dwellings, Gas/Service Station, Retail	41	3			1		
CBLX	Commercial-Sales, 2+ Dwellings, Lumber, Placeholders	42	3			1		
CBPI	Commercial-Sales, 2+ Dwellings, Professional, Irrigated Pasture	41	3			1		
CBVX	Commercial-Sales, 2+ Dwellings, Warehouse, Placeholders	36	3			1		

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
CBXX	Commercial-Sales, 2+ Dwellings, Placeholder, Placeholders	41	3			1		
CBZX	Commercial-Sales, 2+ Dwellings, Unclassifiable, Placeholders	41	3			1		
CCPX	Commercial-Sales, Duplex, Professional, Placeholders	41	2				1	
CDZZ	Commercial-Sales, Triplex, Unclassifiable, Unclassifiable	41	3				1	
CEVX	Commercial-Sales, Fourplex, Warehouse, Placeholders	41	4				1	
CEXX	Commercial-Sales, Fourplex, Placeholder, Placeholders	41	4				1	
CFG4	Commercial-Sales, 5-15 Units, Gas/Service Station, Retail	41					1	1
CGBX	Commercial-Sales, 16+ Units, Mini-Storage, Placeholders	41					1	1
CGHX	Commercial-Sales, 16+ Units, Hotel/Motel/Bd&Bkfst, Placeholders	38					1	1
CGXX	Commercial-Sales, 16+ Units, Placeholder, Placeholders	41					1	1
CIE3	Commercial-Sales, Industrial Park, Farm Mach & Prod, Wholesale	34						
CITX	Commercial-Sales, Industrial Park, Trucking, Placeholders	34						
CIVZ	Commercial-Sales, Industrial Park, Warehouse, Unclassifiable	36						
CM3X	Commercial-Sales, One Mobile Home, Licensed Mo Ho, Placeholders	41	1			1		

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
CM44	Commercial-Sales, One Mobile Home, Unsec Mo Ho, Retail	41	1			1		
CM5X	Commercial-Sales, One Mobile Home, Secured Mo Ho, Placeholders	41	1			1		
CMAX	Commercial-Sales, One Mobile Home, Auto Related, Placeholders	41	1			1		
CMOX	Commercial-Sales, One Mobile Home, Petroleum/Natl Gas, Placeholders	41	1			1		
CMRX	Commercial-Sales, One Mobile Home, Restaurant/Cafe/Bar, Placeholders	41	1			1		
CMTX	Commercial-Sales, One Mobile Home, Trucking, Placeholders	41	1			1		
CMXX	Commercial-Sales, One Mobile Home, Placeholder, Placeholders	41	1			1		
CMZZ	Commercial-Sales, One Mobile Home, Unclassifiable, Unclassifiable	41	1			1		
CN55	Commercial-Sales, 2+ Mo Ho, Secured Mo Ho, Pool	41	3			1		
CP3X	Commercial-Sales, Misc, Structure, Licensed Mo Ho, Placeholders	41	1			1		
CP46	Commercial-Sales, Misc, Structure, Unsec Mo Ho, Permanent Foundation	41	1			1		
CP5X	Commercial-Sales, Misc, Structure, Secured Mo Ho, Placeholders	41	1			1		
CPA4	Commercial-Sales, Misc, Structure, Auto Related, Retail	41						

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
CPAX	Commercial-Sales, Misc, Structure, Auto Related, Placeholders	41						
CPBX	Commercial-Sales, Misc, Structure, Mini-Storage, Placeholders	41						
CPC4	Commercial-Sales, Misc, Structure, Convenience Store, Retail	41						
CPCX	Commercial-Sales, Misc, Structure, Convenience Store, Placeholders	41						
CPEX	Commercial-Sales, Misc, Structure, Farm Mach & Prod, Placeholders	41						
CPF3	Commercial-Sales, Misc, Structure, Food Processing, Wholesale	34						
CPL4	Commercial-Sales, Misc, Structure, Lumber, Retail	41						
CPRX	Commercial-Sales, Misc, Structure, Restaurant/Cafe/Bar, Placeholders	41						
CPSD	Commercial-Sales, Misc, Structure, Supermarket, Dry Farm	41						
CPSZ	Commercial-Sales, Misc, Structure, Supermarket, Unclassifiable	41						
CPT4	Commercial-Sales, Misc, Structure, Trucking, Retail	41						
CPTX	Commercial-Sales, Misc, Structure, Trucking, Placeholders	41						
CPX4	Commercial-Sales, Misc, Structure, Placeholder, Retail	41						

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
CPXX	Commercial-Sales, Misc, Structure, Placeholder, Placeholders	41						
CPZ3	Commercial-Sales, Misc, Structure, Unclassifiable, Wholesale	41						
CPZ4	Commercial-Sales, Misc, Structure, Unclassifiable, Retail	41						
CQV3	Commercial-Sales, Ag Office, Warehouse, Wholesale	36						
CQXX	Commercial-Sales, Ag Office, Placeholder, Placeholders	42						
CS04		41						
CS34	Commercial-Sales, Stand Alone Building, Licensed Mo Ho, Retail	41	1			1		
CS4X	Commercial-Sales, Stand Alone Building, Unsec Mo Ho, Placeholders	41	1			1		
CSA4	Commercial-Sales, Stand Alone Building, Auto Related, Retail	41						
CSAX	Commercial-Sales, Stand Alone Building, Auto Related, Placeholders	41						
CSAZ	Commercial-Sales, Stand Alone Building, Auto Related, Unclassifiable	41						
CSC4	Commercial-Sales, Stand Alone Building, Convenience Store, Retail	41						
CSCX	Commercial-Sales, Stand Alone Building, Convenience Store, Placeholders	41						

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_ flag
CSCZ	Commercial-Sales, Stand Alone Building, Convenience Store, Unclassifiable	41						
CSD4	Commercial-Sales, Stand Alone Building, Department Store, Retail	41						
CSE4	Commercial-Sales, Stand Alone Building, Farm Mach & Prod, Retail	41						
CSEX	Commercial-Sales, Stand Alone Building, Farm Mach & Prod, Placeholders	41						
CSF4	Commercial-Sales, Stand Alone Building, Food Processing, Retail	41						
CSFX	Commercial-Sales, Stand Alone Building, Food Processing, Placeholders	34						
CSFZ	Commercial-Sales, Stand Alone Building, Food Processing, Unclassifiable	41						
CSG4	Commercial-Sales, Stand Alone Building, Gas/Service Station, Retail	41						
CSGX	Commercial-Sales, Stand Alone Building, Gas/Service Station, Placeholders	41						
CSJ4	Commercial-Sales, Stand Alone Building, Medical-Dental, Retail	32						
CSJX	Commercial-Sales, Stand Alone Building, Medical-Dental, Placeholders	32						
CSM4	Commercial-Sales, Stand Alone Building, Market, Retail	41						

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
CSMX	Commercial-Sales, Stand Alone Building, Market, Placeholders	41						
CSN4	Commercial-Sales, Stand Alone Building, Nursery/Flower/GrHs, Retail	41						
CSO3	Commercial-Sales, Stand Alone Building, Petroleum/Natl Gas, Wholesale	41						
CSP4	Commercial-Sales, Stand Alone Building, Professional, Retail	41						
CSPX	Commercial-Sales, Stand Alone Building, Professional, Placeholders	32						
CSQ4	Commercial-Sales, Stand Alone Building, Real Estate Trades, Retail	41						
CSQX	Commercial-Sales, Stand Alone Building, Real Estate Trades, Placeholders	41						
CSQZ	Commercial-Sales, Stand Alone Building, Real Estate Trades, Unclassifiable	41						
CSR4	Commercial-Sales, Stand Alone Building, Restaurant/Cafe/Bar, Retail	41						
CSRX	Commercial-Sales, Stand Alone Building, Restaurant/Cafe/Bar, Placeholders	41						
CSRZ	Commercial-Sales, Stand Alone Building, Restaurant/Cafe/Bar, Unclassifiable	41						
CSS4	Commercial-Sales, Stand Alone Building, Supermarket, Retail	41						

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
CSSX	Commercial-Sales, Stand Alone Building, Supermarket, Placeholders	41						
CSTX	Commercial-Sales, Stand Alone Building, Trucking, Placeholders	41						
CSX4	Commercial-Sales, Stand Alone Building, Placeholder, Retail	41						
CSXR	Commercial-Sales, Stand Alone Building, Placeholder, Row Crop	41						
CSXX	Commercial-Sales, Stand Alone Building, Placeholder, Placeholders	41						
CSZ4	Commercial-Sales, Stand Alone Building, Unclassifiable, Retail	41						
CSZR	Commercial-Sales, Stand Alone Building, Unclassifiable, Row Crop	41						
CSZX	Commercial-Sales, Stand Alone Building, Unclassifiable, Placeholders	41						
CSZZ	Commercial-Sales, Stand Alone Building, Unclassifiable, Unclassifiable	41						
CTA4	Commercial-Sales, Strip Development, Auto Related, Retail	41						
CTAX	Commercial-Sales, Strip Development, Auto Related, Placeholders	41						
CTAZ	Commercial-Sales, Strip Development, Auto Related, Unclassifiable	41						
CTG4	Commercial-Sales, Strip Development, Gas/Service Station, Retail	41						

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
CTM4	Commercial-Sales, Strip Development, Market, Retail	41						
CTPR	Commercial-Sales, Strip Development, Professional, Row Crop	41						
CTPX	Commercial-Sales, Strip Development, Professional, Placeholders	41						
CTQ4	Commercial-Sales, Strip Development, Real Estate Trades, Retail	41						
CTQX	Commercial-Sales, Strip Development, Real Estate Trades, Placeholders	41						
CTQZ	Commercial-Sales, Strip Development, Real Estate Trades, Unclassifiable	41						
CTR4	Commercial-Sales, Strip Development, Restaurant/Cafe/Bar, Retail	41						
CTRX	Commercial-Sales, Strip Development, Restaurant/Cafe/Bar, Placeholders	41						
CTRZ	Commercial-Sales, Strip Development, Restaurant/Cafe/Bar, Unclassifiable	41						
CTS4	Commercial-Sales, Strip Development, Supermarket, Retail	41						
GXBX		36						
CTSX	Commercial-Sales, Strip Development, Supermarket, Placeholders	41						
CTSZ	Commercial-Sales, Strip Development, Supermarket, Unclassifiable	41						

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
CTX4	Commercial-Sales, Strip Development, Placeholder, Retail	41						
CTXX	Commercial-Sales, Strip Development, Placeholder, Placeholders	41						
CTZ4	Commercial-Sales, Strip Development, Unclassifiable, Retail	41						
CTZX	Commercial-Sales, Strip Development, Unclassifiable, Placeholders	41						
CTZZ	Commercial-Sales, Strip Development, Unclassifiable, Unclassifiable	41						
CUM4	Commercial-Sales, Comm Ofc Complex, Market, Retail	41						
CUPX	Commercial-Sales, Comm Ofc Complex, Professional, Placeholders	32						
CUQX	Commercial-Sales, Comm Ofc Complex, Real Estate Trades, Placeholders	32						
CUXX	Commercial-Sales, Comm Ofc Complex, Placeholder, Placeholders	32						
CV54	Commercial-Sales, Neighb Shoppg Center, Secured Mo Ho, Retail	41						
CVA4	Commercial-Sales, Neighb Shoppg Center, Auto Related, Retail	41						
CVC4	Commercial-Sales, Neighb Shoppg Center, Convenience Store, Retail	41						
CVG4	Commercial-Sales, Neighb Shoppg Center, Gas/Service Station, Retail	41						

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
CVL4	Commercial-Sales, Neighb Shoppg Center, Lumber, Retail	41						
CVM4	Commercial-Sales, Neighb Shoppg Center, Market, Retail	41						
CVR4	Commercial-Sales, Neighb Shoppg Center, Restaurant/Cafe/Bar, Retail	41						
CVRX	Commercial-Sales, Neighb Shoppg Center, Restaurant/Cafe/Bar, Placeholders	41						
CVS4	Commercial-Sales, Neighb Shoppg Center, Supermarket, Retail	41						
CVSX	Commercial-Sales, Neighb Shoppg Center, Supermarket, Placeholders	41						
CVX4	Commercial-Sales, Neighb Shoppg Center, Placeholder, Retail	41						
CVXX	Commercial-Sales, Neighb Shoppg Center, Placeholder, Placeholders	41						
CVZ4	Commercial-Sales, Neighb Shoppg Center, Unclassifiable, Retail	41						
CWD4	Commercial-Sales, Major Shopping Center, Department Store, Retail	40						
CWS4	Commercial-Sales, Major Shopping Center, Supermarket, Retail	41						
CWSX	Commercial-Sales, Major Shopping Center, Supermarket, Placeholders	41						
CWX4	Commercial-Sales, Major Shopping Center, Placeholder, Retail	41						

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
CWXV	Commercial-Sales, Major Shopping Center, Placeholder, Vacant Land	41						
CWXX	Commercial-Sales, Major Shopping Center, Placeholder, Placeholders	41						
CWZ4	Commercial-Sales, Major Shopping Center, Unclassifiable, Retail	41						
CX54	Commercial-Sales, Placeholder, Secured Mo Ho, Retail	41	1			1		
CXA4	Commercial-Sales, Placeholder, Auto Related, Retail	41						
CXAX	Commercial-Sales, Placeholder, Auto Related, Placeholders	41						
CXCX	Commercial-Sales, Placeholder, Convenience Store, Placeholders	41						
AMOF		42	1			1		
CXDX	Commercial-Sales, Placeholder, Department Store, Placeholders	41						
CXE4	Commercial-Sales, Placeholder, Farm Mach & Prod, Retail	41						
CXEX	Commercial-Sales, Placeholder, Farm Mach & Prod, Placeholders	41						
CXF4	Commercial-Sales, Placeholder, Food Processing, Retail	41						
CXFX	Commercial-Sales, Placeholder, Food Processing, Placeholders	41						

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
CXG4	Commercial-Sales, Placeholder, Gas/Service Station, Retail	41						
CXGX	Commercial-Sales, Placeholder, Gas/Service Station, Placeholders	41						
CXIX	Commercial-Sales, Placeholder, Farm Labor Camp, Placeholders	41				1		1
CXJX	Commercial-Sales, Placeholder, Medical-Dental, Placeholders	32						
CXLX	Commercial-Sales, Placeholder, Lumber, Placeholders	41						
CXMX	Commercial-Sales, Placeholder, Market, Placeholders	41						
CXO3	Commercial-Sales, Placeholder, Petroleum/Natl Gas, Wholesale	41						
CXOX	Commercial-Sales, Placeholder, Petroleum/Natl Gas, Placeholders	41						
CXPX	Commercial-Sales, Placeholder, Professional, Placeholders	32						
CXRX	Commercial-Sales, Placeholder, Restaurant/Cafe/Bar, Placeholders	41						
CXRZ	Commercial-Sales, Placeholder, Restaurant/Cafe/Bar, Unclassifiable	41						
CXSX	Commercial-Sales, Placeholder, Supermarket, Placeholders	41						

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
CXSZ	Commercial-Sales, Placeholder, Supermarket, Unclassifiable	41						
CXTX	Commercial-Sales, Placeholder, Trucking, Placeholders	41						
CXWX	Commercial-Sales, Placeholder, Winery, Placeholders	41						
CXX4	Commercial-Sales, Placeholder, Placeholder, Retail	41						
CXZ4	Commercial-Sales, Placeholder, Unclassifiable, Retail	41						
CXZX	Commercial-Sales, Placeholder, Unclassifiable, Placeholders	41						
CZA4	Commercial-Sales, Unclassifiable, Auto Related, Retail	41						
CZQX	Commercial-Sales, Unclassifiable, Real Estate Trades, Placeholders	41						
CZRZ	Commercial-Sales, Unclassifiable, Restaurant/Cafe/Bar, Unclassifiable	41						
CZXD	Commercial-Sales, Unclassifiable, Placeholder, Dry Farm	41						
CZXX	Commercial-Sales, Unclassifiable, Placeholder, Placeholders	41						
CZZX	Commercial-Sales, Unclassifiable, Unclassifiable, Placeholders	41						
CZZZ	Commercial-Sales, Unclassifiable, Unclassifiable, Unclassifiable	41						

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
DAAX	Commercial-Service, One Dwelling, Auto Related, Placeholders	41	1			1		
DAAZ	Commercial-Service, One Dwelling, Auto Related, Unclassifiable	41	1			1		
DABX	Commercial-Service, One Dwelling, Mini-Storage, Placeholders	36	1			1		
DAJX	Commercial-Service, One Dwelling, Medical-Dental, Placeholders	32	1			1		
DAJZ	Commercial-Service, One Dwelling, Medical-Dental, Unclassifiable	32	1			1		
DAPX	Commercial-Service, One Dwelling, Professional, Placeholders	38	1				1	
DAPZ	Commercial-Service, One Dwelling, Professional, Unclassifiable	32	1			1		
DAXX	Commercial-Service, One Dwelling, Placeholder, Placeholders	32	1			1		
DAZ4	Commercial-Service, One Dwelling, Unclassifiable, Retail	41	1			1		
DFHX	Commercial-Service, 5-15 Units, Hotel/Motel/Bd&Bkfst, Placeholders	38					1	1
DIP4	Commercial-Service, Industrial Park, Professional, Retail	34						
DIPZ	Commercial-Service, Industrial Park, Professional, Unclassifiable	34						
DPA4	Commercial-Service, Misc, Structure, Auto Related, Retail	41						
DPAX	Commercial-Service, Misc, Structure, Auto Related, Placeholders	41						

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
DPB4	Commercial-Service, Misc, Structure, Mini-Storage, Retail	41						
DPBX	Commercial-Service, Misc, Structure, Mini-Storage, Placeholders	41						
DPH5	Commercial-Service, Misc, Structure, Hotel/Motel/Bd&Bkfst, Pool	38					1	1
DPJX	Commercial-Service, Misc, Structure, Medical-Dental, Placeholders	32						
DPPZ	Commercial-Service, Misc, Structure, Professional, Unclassifiable	32						
DPZZ	Commercial-Service, Misc, Structure, Unclassifiable, Unclassifiable	32						
DSA4	Commercial-Service, Stand Alone Building, Auto Related, Retail	41						
DSAX	Commercial-Service, Stand Alone Building, Auto Related, Placeholders	41						
DSAZ	Commercial-Service, Stand Alone Building, Auto Related, Unclassifiable	41						
DSBX	Commercial-Service, Stand Alone Building, Mini-Storage, Placeholders	36						
DSEZ	Commercial-Service, Stand Alone Building, Farm Mach & Prod, Unclassifiable	41						
DSG4	Commercial-Service, Stand Alone Building, Gas/Service Station, Retail	41						

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_flag**
DSGX	Commercial-Service, Stand Alone Building, Gas/Service Station, Placeholders	41						
DSHX	Commercial-Service, Stand Alone Building, Hotel/Motel/Bd&Bkfst, Placeholders	38					1	1
DSJ4	Commercial-Service, Stand Alone Building, Medical-Dental, Retail	32						
DSJX	Commercial-Service, Stand Alone Building, Medical-Dental, Placeholders	32						
DSJZ	Commercial-Service, Stand Alone Building, Medical-Dental, Unclassifiable	32						
DSPX	Commercial-Service, Stand Alone Building, Professional, Placeholders	32						
DSPZ	Commercial-Service, Stand Alone Building, Professional, Unclassifiable	32						
DSQX	Commercial-Service, Stand Alone Building, Real Estate Trades, Placeholders	41						
DSR4	Commercial-Service, Stand Alone Building, Restaurant/Cafe/Bar, Retail	41						
DSRX	Commercial-Service, Stand Alone Building, Restaurant/Cafe/Bar, Placeholders	41						
DSSZ	Commercial-Service, Stand Alone Building, Supermarket, Unclassifiable	41						
DSTX	Commercial-Service, Stand Alone Building, Trucking, Placeholders	41						

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
DSXX	Commercial-Service, Stand Alone Building, Placeholder, Placeholders	41						
DSZX	Commercial-Service, Stand Alone Building, Unclassifiable, Placeholders	41						
DSZZ	Commercial-Service, Stand Alone Building, Unclassifiable, Unclassifiable	41						
DTJ3	Commercial-Service, Strip Development, Medical-Dental, Wholesale	32						
DTJX	Commercial-Service, Strip Development, Medical-Dental, Placeholders	32						
DTP4	Commercial-Service, Strip Development, Professional, Retail	41						
DTPZ	Commercial-Service, Strip Development, Professional, Unclassifiable	32						
DTQX	Commercial-Service, Strip Development, Real Estate Trades, Placeholders	32						
AMXR		42	1			1		
DTRX	Commercial-Service, Strip Development, Restaurant/Cafe/Bar, Placeholders	41						
DTZ4	Commercial-Service, Strip Development, Unclassifiable, Retail	41						
DTZX	Commercial-Service, Strip Development, Unclassifiable, Placeholders	41						
DTZZ	Commercial-Service, Strip Development, Unclassifiable, Unclassifiable	41						

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
DUJX	Commercial-Service, Comm Ofc Complex, Medical-Dental, Placeholders	32						
DUQX	Commercial-Service, Comm Ofc Complex, Real Estate Trades, Placeholders	41						
DUXX	Commercial-Service, Comm Ofc Complex, Placeholder, Placeholders	32						
DVJX	Commercial-Service, Neighb Shoppg Center, Medical-Dental, Placeholders	32						
DVRX	Commercial-Service, Neighb Shoppg Center, Restaurant/Cafe/Bar, Placeholders	41						
DVXX	Commercial-Service, Neighb Shoppg Center, Placeholder, Placeholders	41						
DXJX	Commercial-Service, Placeholder, Medical-Dental, Placeholders	32						
DXPX	Commercial-Service, Placeholder, Professional, Placeholders	32						
DXVW	Commercial-Service, Placeholder, Warehouse, Walnuts	42						
EAHX	Commercial-Rec, One Dwelling, Hotel/Motel/Bd&Bkfst, Placeholders	38					1	1
EL55	Commercial-Rec, Lodging, Secured Mo Ho, Pool	38					1	1
EPXX	Commercial-Rec, Misc, Structure, Placeholder, Placeholders	42						
EPZ4	Commercial-Rec, Misc, Structure, Unclassifiable, Retail	41						

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_flag**
EPZX	Commercial-Rec, Misc, Structure, Unclassifiable, Placeholders	42						
ESRX	Commercial-Rec, Stand Alone Building, Restaurant/Cafe/Bar, Placeholders	41						
ESX4	Commercial-Rec, Stand Alone Building, Placeholder, Retail	41						
ESXX	Commercial-Rec, Stand Alone Building, Placeholder, Placeholders	41						
ESZ4	Commercial-Rec, Stand Alone Building, Unclassifiable, Retail	41						
ESZX	Commercial-Rec, Stand Alone Building, Unclassifiable, Placeholders	41						
ESZZ	Commercial-Rec, Stand Alone Building, Unclassifiable, Unclassifiable	41						
ETR4	Commercial-Rec, Strip Development, Restaurant/Cafe/Bar, Retail	41						
ETZ4	Commercial-Rec, Strip Development, Unclassifiable, Retail	41						
EXHX	Commercial-Rec, Placeholder, Hotel/Motel/Bd&Bkfst, Placeholders	38					1	1
EZX4	Commercial-Rec, Unclassifiable, Placeholder, Retail	41						
FAXX	Commercial-Finance, One Dwelling, Placeholder, Placeholders	41						

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
FSPX	Commercial-Finance, Stand Alone Building, Professional, Placeholders	32						
FSXX	Commercial-Finance, Stand Alone Building, Placeholder, Placeholders	32						
FSZZ	Commercial-Finance, Stand Alone Building, Unclassifiable, Unclassifiable	32						
FTZZ	Commercial-Finance, Strip Development, Unclassifiable, Unclassifiable	32						
FUQZ	Commercial-Finance, Comm Ofc Complex, Real Estate Trades, Unclassifiable	32						
FUXX	Commercial-Finance, Comm Ofc Complex, Placeholder, Placeholders	32						
FXXX	Commercial-Finance, Placeholder, Placeholder, Placeholders	32						
GAPX	Commercial-Other, One Dwelling, Professional, Placeholders	32	1			1		
GAXX	Commercial-Other, One Dwelling, Placeholder, Placeholders	32	1			1		
GAZX	Commercial-Other, One Dwelling, Unclassifiable, Placeholders	32	1			1		
GAZZ	Commercial-Other, One Dwelling, Unclassifiable, Unclassifiable	32	1			1		
GBHX	Commercial-Other, 2+ Dwellings, Hotel/Motel/Bd&Bkfst, Placeholders	38	2					

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_flag**
GBLX	Commercial-Other, 2+ Dwellings, Lumber, Placeholders	41	2			1		
GBPX	Commercial-Other, 2+ Dwellings, Professional, Placeholders	32	2			1		
GLH5	Commercial-Other, Lodging, Hotel/Motel/Bd&Bkfst, Pool	38					1	1
GLHX	Commercial-Other, Lodging, Hotel/Motel/Bd&Bkfst, Placeholders	38					1	1
GLXX	Commercial-Other, Lodging, Placeholder, Placeholders	38					1	
GMFX	Commercial-Other, One Mobile Home, Food Processing, Placeholders	36	1			1		
GMN3	Commercial-Other, One Mobile Home, Nursery/Flower/GrHs, Wholesale	42	1			1		
GPAZ	Commercial-Other, Misc, Structure, Auto Related, Unclassifiable	41						
GPBX	Commercial-Other, Misc, Structure, Mini-Storage, Placeholders	36						
GPSZ	Commercial-Other, Misc, Structure, Supermarket, Unclassifiable	41						
GPVX	Commercial-Other, Misc, Structure, Warehouse, Placeholders	36						
GPVZ	Commercial-Other, Misc, Structure, Warehouse, Unclassifiable	36						

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
GPXX	Commercial-Other, Misc, Structure, Placeholder, Placeholders	36						
GPXZ	Commercial-Other, Misc, Structure, Placeholder, Unclassifiable	36						
GPZZ	Commercial-Other, Misc, Structure, Unclassifiable, Unclassifiable	36						
GSAX	Commercial-Other, Stand Alone Building, Auto Related, Placeholders	41						
GSAZ	Commercial-Other, Stand Alone Building, Auto Related, Unclassifiable	41						
GSF3	Commercial-Other, Stand Alone Building, Food Processing, Wholesale	36						
GSG4	Commercial-Other, Stand Alone Building, Gas/Service Station, Retail	41						
GSJX	Commercial-Other, Stand Alone Building, Medical-Dental, Placeholders	32						
GSPZ	Commercial-Other, Stand Alone Building, Professional, Unclassifiable	32						
GSVZ	Commercial-Other, Stand Alone Building, Warehouse, Unclassifiable	36						
GSXX	Commercial-Other, Stand Alone Building, Placeholder, Placeholders	41						
GSZZ	Commercial-Other, Stand Alone Building, Unclassifiable, Unclassifiable	41						

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
GTJZ	Commercial-Other, Strip Development, Medical-Dental, Unclassifiable	32						
GTVX	Commercial-Other, Strip Development, Warehouse, Placeholders	36						
GTZX	Commercial-Other, Strip Development, Unclassifiable, Placeholders	41						
GTZZ	Commercial-Other, Strip Development, Unclassifiable, Unclassifiable	41						
GUPX	Commercial-Other, Comm Ofc Complex, Professional, Placeholders	32						
GUXX	Commercial-Other, Comm Ofc Complex, Placeholder, Placeholders	32						
GUZ4	Commercial-Other, Comm Ofc Complex, Unclassifiable, Retail	32						
GVXX	Commercial-Other, Neighb Shoppg Center, Placeholder, Placeholders	41						
GWX4	Commercial-Other, Major Shopping Center, Placeholder, Retail	40						
GXFX	Commercial-Other, Placeholder, Food Processing, Placeholders	34						
GXGX	Commercial-Other, Placeholder, Gas/Service Station, Placeholders	41						
GXHX	Commercial-Other, Placeholder, Hotel/Motel/Bd&Bkfst, Placeholders	38					1	1

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
GXJX	Commercial-Other, Placeholder, Medical-Dental, Placeholders	32						
GXSX	Commercial-Other, Placeholder, Supermarket, Placeholders	41						
GXVX	Commercial-Other, Placeholder, Warehouse, Placeholders	36						
GXWX	Commercial-Other, Placeholder, Winery, Placeholders	41						
GXXG	Commercial-Other, Placeholder, Placeholder, Grapes	42						
GXXX	Commercial-Other, Placeholder, Placeholder, Placeholders	41						
GZZZ	Commercial-Other, Unclassifiable, Unclassifiable, Unclassifiable	41						
IAW5	Industrial-Manufacture, One Dwelling, Winery, Pool	41	1			1		
IAXD	Industrial-Manufacture, One Dwelling, Placeholder, Dry Farm	42	1			1		
IAXX	Industrial-Manufacture, One Dwelling, Placeholder, Placeholders	34	1			1		
IBXX	Industrial-Manufacture, 2+ Dwellings, Placeholder, Placeholders	34	3			1		
IBZZ	Industrial-Manufacture, 2+ Dwellings, Unclassifiable, Unclassifiable	34	3			1		

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
IIF3	Industrial-Manufacture, Industrial Park, Food Processing, Wholesale	34						
IIFP	Industrial-Manufacture, Industrial Park, Food Processing, Pistachios	34						
IITX	Industrial-Manufacture, Industrial Park, Trucking, Placeholders	34						
IIV3	Industrial-Manufacture, Industrial Park, Warehouse, Wholesale	36						
IIVZ	Industrial-Manufacture, Industrial Park, Warehouse, Unclassifiable	36						
IIXV	Industrial-Manufacture, Industrial Park, Placeholder, Vacant Land	34						
IIXX	Industrial-Manufacture, Industrial Park, Placeholder, Placeholders	34						
IIZ3	Industrial-Manufacture, Industrial Park, Unclassifiable, Wholesale	41						
IIZX	Industrial-Manufacture, Industrial Park, Unclassifiable, Placeholders	34						
IIZZ	Industrial-Manufacture, Industrial Park, Unclassifiable, Unclassifiable	34						

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
IPFX	Industrial-Manufacture, Misc, Structure, Food Processing, Placeholders	34						
IPXX	Industrial-Manufacture, Misc, Structure, Placeholder, Placeholders	34						
IPZX	Industrial-Manufacture, Misc, Structure, Unclassifiable, Placeholders	34						
IPZZ	Industrial-Manufacture, Misc, Structure, Unclassifiable, Unclassifiable	34						
ISA3	Industrial-Manufacture, Stand Alone Building, Auto Related, Wholesale	41						
ISAZ	Industrial-Manufacture, Stand Alone Building, Auto Related, Unclassifiable	41						
ISF3	Industrial-Manufacture, Stand Alone Building, Food Processing, Wholesale	34						
ISLX	Industrial-Manufacture, Stand Alone Building, Lumber, Placeholders	41						
ISQZ	Industrial-Manufacture, Stand Alone Building, Real Estate Trades, Unclassifiable	32						
ISX3	Industrial-Manufacture, Stand Alone Building, Placeholder, Wholesale	34						

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
ISXX	Industrial-Manufacture, Stand Alone Building, Placeholder, Placeholders	34						
ISZ3	Industrial-Manufacture, Stand Alone Building, Unclassifiable, Wholesale	41						
ISZX	Industrial-Manufacture, Stand Alone Building, Unclassifiable, Placeholders	34						
ISZZ	Industrial-Manufacture, Stand Alone Building, Unclassifiable, Unclassifiable	34						
IXEX	Industrial-Manufacture, Placeholder, Farm Mach & Prod, Placeholders	41						
IXF3	Industrial-Manufacture, Placeholder, Food Processing, Wholesale	41						
IXFG	Industrial-Manufacture, Placeholder, Food Processing, Grapes	34						
IXFO	Industrial-Manufacture, Placeholder, Food Processing, Olives	34						
IXFX	Industrial-Manufacture, Placeholder, Food Processing, Placeholders	34						
IXW3	Industrial-Manufacture, Placeholder, Winery, Wholesale	41						

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
IXXD	Industrial-Manufacture, Placeholder, Placeholder, Dry Farm	42						
IXXR	Industrial-Manufacture, Placeholder, Placeholder, Row Crop	42						
IXXV	Industrial-Manufacture, Placeholder, Placeholder, Vacant Land	42						
IXXX	Industrial-Manufacture, Placeholder, Placeholder, Placeholders	34						
IZEZ	Industrial-Manufacture, Unclassifiable, Farm Mach & Prod, Unclassifiable	34						
IZZZ	Industrial-Manufacture, Unclassifiable, Unclassifiable, Unclassifiable	42						
KIVX	Industrial-Other, Industrial Park, Warehouse, Placeholders	36						
KIVZ	Industrial-Other, Industrial Park, Warehouse, Unclassifiable	36						
KIXX	Industrial-Other, Industrial Park, Placeholder, Placeholders	34						
KM5X	Industrial-Other, One Mobile Home, Secured Mo Ho, Placeholders	34						
KPVZ	Industrial-Other, Misc, Structure, Warehouse, Unclassifiable	36						

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
KPZX	Industrial-Other, Misc, Structure, Unclassifiable, Placeholders	34						
KPZZ	Industrial-Other, Misc, Structure, Unclassifiable, Unclassifiable	34						
KQZZ	Industrial-Other, Ag Office, Unclassifiable, Unclassifiable	34						
KSXX	Industrial-Other, Stand Alone Building, Placeholder, Placeholders	34						
KXFX	Industrial-Other, Placeholder, Food Processing, Placeholders	34						
KXXX	Industrial-Other, Placeholder, Placeholder, Placeholders	34						
KZFX	Industrial-Other, Unclassifiable, Food Processing, Placeholders	34						
KZXX	Industrial-Other, Unclassifiable, Placeholder, Placeholders	34						
LA3A	Farmland Security Zone, One Dwelling, Licensed Mo Ho, Almonds	42	1			1		
LA8G	Farmland Security Zone, One Dwelling, Cons Esmnt Subvened, Grapes	42	1			1		
LAFA	Farmland Security Zone, One Dwelling, Food Processing, Almonds	34	1			1		
LAWG	Farmland Security Zone, One Dwelling, Winery, Grapes	41	1			1		

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_ flag
LAXA	Farmland Security Zone, One Dwelling, Placeholder, Almonds	42	1			1		
LAXE	Farmland Security Zone, One Dwelling, Placeholder, Dairy	42	1			1		
LAXF	Farmland Security Zone, One Dwelling, Placeholder, Figs	42	1			1		
LAXG	Farmland Security Zone, One Dwelling, Placeholder, Grapes	42	1			1		
LAXI	Farmland Security Zone, One Dwelling, Placeholder, Irrigated Pasture	42	1			1		
LAXK	Farmland Security Zone, One Dwelling, Placeholder, Kiwi	42	1			1		
LAXP	Farmland Security Zone, One Dwelling, Placeholder, Pistachios	42	1			1		
LAXQ	Farmland Security Zone, One Dwelling, Placeholder, Peaches	42	1			1		
LAXR	Farmland Security Zone, One Dwelling, Placeholder, Row Crop	42	1			1		
LAXS	Farmland Security Zone, One Dwelling, Placeholder, Pomegranates	42	1			1		
PXXA	Ag Preserve, Placeholder, Placeholder, Almonds	42						
LAXW	Farmland Security Zone, One Dwelling, Placeholder, Walnuts	42	1			1		
LAXX	Farmland Security Zone, One Dwelling, Placeholder, Placeholders	42	1			1		
LAXZ	Farmland Security Zone, One Dwelling, Placeholder, Unclassifiable	42	1			1		

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
LB3A	Farmland Security Zone, 2+ Dwellings, Licensed Mo Ho, Almonds	42	2			1		
LB3E	Farmland Security Zone, 2+ Dwellings, Licensed Mo Ho, Dairy	42	2			1		
LB3G	Farmland Security Zone, 2+ Dwellings, Licensed Mo Ho, Grapes	42	2			1		
LB3I	Farmland Security Zone, 2+ Dwellings, Licensed Mo Ho, Irrigated Pasture	42	2			1		
LB3R	Farmland Security Zone, 2+ Dwellings, Licensed Mo Ho, Row Crop	42	2			1		
LB3Z	Farmland Security Zone, 2+ Dwellings, Licensed Mo Ho, Unclassifiable	42	2			1		
LB4A	Farmland Security Zone, 2+ Dwellings, Unsec Mo Ho, Almonds	42	2			1		
LB4E	Farmland Security Zone, 2+ Dwellings, Unsec Mo Ho, Dairy	42	2			1		
LB4Z	Farmland Security Zone, 2+ Dwellings, Unsec Mo Ho, Unclassifiable	42	2			1		
LB5A	Farmland Security Zone, 2+ Dwellings, Secured Mo Ho, Almonds	42	2			1		
LB5E	Farmland Security Zone, 2+ Dwellings, Secured Mo Ho, Dairy	42	2			1		
LB5G	Farmland Security Zone, 2+ Dwellings, Secured Mo Ho, Grapes	42	2			1		

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_ flag
LB5R	Farmland Security Zone, 2+ Dwellings, Secured Mo Ho, Row Crop	42	2			1		
LB5X	Farmland Security Zone, 2+ Dwellings, Secured Mo Ho, Placeholders	42	2			1		
LBVG	Farmland Security Zone, 2+ Dwellings, Warehouse, Grapes	42	2			1		
LBXA	Farmland Security Zone, 2+ Dwellings, Placeholder, Almonds	42	2			1		
LBXE	Farmland Security Zone, 2+ Dwellings, Placeholder, Dairy	42	2			1		
LBXF	Farmland Security Zone, 2+ Dwellings, Placeholder, Figs	42	2			1		
LBXG	Farmland Security Zone, 2+ Dwellings, Placeholder, Grapes	42	2			1		
LBXI	Farmland Security Zone, 2+ Dwellings, Placeholder, Irrigated Pasture	42	2			1		
LBXR	Farmland Security Zone, 2+ Dwellings, Placeholder, Row Crop	42	2			1		
LBXZ	Farmland Security Zone, 2+ Dwellings, Placeholder, Unclassifiable	42	2			1		
LM3A	Farmland Security Zone, One Mobile Home, Licensed Mo Ho, Almonds	42	1			1		
LM3G	Farmland Security Zone, One Mobile Home, Licensed Mo Ho, Grapes	42	1			1		
LM3R	Farmland Security Zone, One Mobile Home, Licensed Mo Ho, Row Crop	42	1			1		

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
LM4A	Farmland Security Zone, One Mobile Home, Unsec Mo Ho, Almonds	42	1			1		
LM4G	Farmland Security Zone, One Mobile Home, Unsec Mo Ho, Grapes	42	1			1		
LM5A	Farmland Security Zone, One Mobile Home, Secured Mo Ho, Almonds	42	1			1		
LM5F	Farmland Security Zone, One Mobile Home, Secured Mo Ho, Figs	42	1			1		
LM5G	Farmland Security Zone, One Mobile Home, Secured Mo Ho, Grapes	42	1			1		
LM5I	Farmland Security Zone, One Mobile Home, Secured Mo Ho, Irrigated Pasture	42	1			1		
LM5R	Farmland Security Zone, One Mobile Home, Secured Mo Ho, Row Crop	42	1			1		
LM5Z	Farmland Security Zone, One Mobile Home, Secured Mo Ho, Unclassifiable	42	1			1		
LMXG	Farmland Security Zone, One Mobile Home, Placeholder, Grapes	42	1			1		
LN3G	Farmland Security Zone, 2+ Mo Ho, Licensed Mo Ho, Grapes	42	2			1		
GXLX		42						
GXTX		36						
LN3R	Farmland Security Zone, 2+ Mo Ho, Licensed Mo Ho, Row Crop	42	2			1		

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
LN5A	Farmland Security Zone, 2+ Mo Ho, Secured Mo Ho, Almonds	42	2			1		
LPXG	Farmland Security Zone, Misc, Structure, Placeholder, Grapes	42						
LQXA	Farmland Security Zone, Ag Office, Placeholder, Almonds	42						
LSXF	Farmland Security Zone, Stand Alone Building, Placeholder, Figs	42						
LSXG	Farmland Security Zone, Stand Alone Building, Placeholder, Grapes	42						
LSXZ	Farmland Security Zone, Stand Alone Building, Placeholder, Unclassifiable	42						
LX8R	Farmland Security Zone, Placeholder, Cons Esmnt Subvened, Row Crop	42						
LXXA	Farmland Security Zone, Placeholder, Placeholder, Almonds	42						
LXXC	Farmland Security Zone, Placeholder, Placeholder, Citrus	42						
LXXE	Farmland Security Zone, Placeholder, Placeholder, Dairy	42						
LXXF	Farmland Security Zone, Placeholder, Placeholder, Figs	42						
LXXG	Farmland Security Zone, Placeholder, Placeholder, Grapes	42						
LXXI	Farmland Security Zone, Placeholder, Placeholder, Irrigated Pasture	42						

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
LXXJ	Farmland Security Zone, Placeholder, Placeholder, Grazing	42						
LXXP	Farmland Security Zone, Placeholder, Placeholder, Pistachios	42						
LXXR	Farmland Security Zone, Placeholder, Placeholder, Row Crop	42						
LXXT	Farmland Security Zone, Placeholder, Placeholder, Commercial Animal	42						
LXXW	Farmland Security Zone, Placeholder, Placeholder, Walnuts	42						
LXXX	Farmland Security Zone, Placeholder, Placeholder, Placeholders	42						
LXXZ	Farmland Security Zone, Placeholder, Placeholder, Unclassifiable	42						
MDXX	Mining/Quarrying, Triplex, Placeholder, Placeholders	42	3				1	
MOXX	Mining/Quarrying, Cabin, Placeholder, Placeholders	42	1			1		
MPXD	Mining/Quarrying, Misc, Structure, Placeholder, Dry Farm	42						
MPZX	Mining/Quarrying, Misc, Structure, Unclassifiable, Placeholders	42						
MRXX	Mining/Quarrying, , Placeholder, Placeholders	42						
MXXX	Mining/Quarrying, Placeholder, Placeholder, Placeholders	42						

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
MZXX	Mining/Quarrying, Unclassifiable, Placeholder, Placeholders	42						
NAX5	Non-Renewal (Ag Pr), One Dwelling, Placeholder, Pool	42	1			1		
NAXA	Non-Renewal (Ag Pr), One Dwelling, Placeholder, Almonds	42	1			1		
NAXC	Non-Renewal (Ag Pr), One Dwelling, Placeholder, Citrus	42	1			1		
NAXE	Non-Renewal (Ag Pr), One Dwelling, Placeholder, Dairy	42	1			1		
NAXG	Non-Renewal (Ag Pr), One Dwelling, Placeholder, Grapes	42	1			1		
NAXJ	Non-Renewal (Ag Pr), One Dwelling, Placeholder, Grazing	42	1			1		
NAXP	Non-Renewal (Ag Pr), One Dwelling, Placeholder, Pistachios	42	1			1		
NAXR	Non-Renewal (Ag Pr), One Dwelling, Placeholder, Row Crop	42	1			1		
NAXX	Non-Renewal (Ag Pr), One Dwelling, Placeholder, Placeholders	42	1			1		
NAXZ	Non-Renewal (Ag Pr), One Dwelling, Placeholder, Unclassifiable	42	1			1		
NB3G	Non-Renewal (Ag Pr), 2+ Dwellings, Licensed Mo Ho, Grapes	42	2			1		
NB5G	Non-Renewal (Ag Pr), 2+ Dwellings, Secured Mo Ho, Grapes	42	2			1		
NB5O	Non-Renewal (Ag Pr), 2+ Dwellings, Secured Mo Ho, Olives	42	2			1		

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_ flag
NB5r	Non-Renewal (Ag Pr), 2+ Dwellings, Secured Mo Ho, Row Crop	42	2			1		
NBXG	Non-Renewal (Ag Pr), 2+ Dwellings, Placeholder, Grapes	42	2			1		
NBXJ	Non-Renewal (Ag Pr), 2+ Dwellings, Placeholder, Grazing	42	2			1		
NBXR	Non-Renewal (Ag Pr), 2+ Dwellings, Placeholder, Row Crop	42	2			1		
NBXZ	Non-Renewal (Ag Pr), 2+ Dwellings, Placeholder, Unclassifiable	42	2			1		
NM3G	Non-Renewal (Ag Pr), One Mobile Home, Licensed Mo Ho, Grapes	42	1			1		
NM3J	Non-Renewal (Ag Pr), One Mobile Home, Licensed Mo Ho, Grazing	42	1			1		
NM5A	Non-Renewal (Ag Pr), One Mobile Home, Secured Mo Ho, Almonds	42	1			1		
NM5R	Non-Renewal (Ag Pr), One Mobile Home, Secured Mo Ho, Row Crop	42	1			1		
NM5S	Non-Renewal (Ag Pr), One Mobile Home, Secured Mo Ho, Pomegranates	42	1			1		
NN5G	Non-Renewal (Ag Pr), 2+ Mo Ho, Secured Mo Ho, Grapes	42	2			1		
NPXJ	Non-Renewal (Ag Pr), Misc, Structure, Placeholder, Grazing	42						
NQ3Z	Non-Renewal (Ag Pr), Ag Office, Licensed Mo Ho, Unclassifiable	42						

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
NXXA	Non-Renewal (Ag Pr), Placeholder, Placeholder, Almonds	42						
NXXD	Non-Renewal (Ag Pr), Placeholder, Placeholder, Dry Farm	42						
NXXF	Non-Renewal (Ag Pr), Placeholder, Placeholder, Figs	42						
NXXG	Non-Renewal (Ag Pr), Placeholder, Placeholder, Grapes	42						
NXXI	Non-Renewal (Ag Pr), Placeholder, Placeholder, Irrigated Pasture	42						
NXXJ	Non-Renewal (Ag Pr), Placeholder, Placeholder, Grazing	42						
NXXN	Non-Renewal (Ag Pr), Placeholder, Placeholder, Apples	42						
NXXP	Non-Renewal (Ag Pr), Placeholder, Placeholder, Pistachios	42						
NXXR	Non-Renewal (Ag Pr), Placeholder, Placeholder, Row Crop	42						
NXXS	Non-Renewal (Ag Pr), Placeholder, Placeholder, Pomegranates	42						
NXXV	Non-Renewal (Ag Pr), Placeholder, Placeholder, Vacant Land	42						
NXXX	Non-Renewal (Ag Pr), Placeholder, Placeholder, Placeholders	42						
NXXZ	Non-Renewal (Ag Pr), Placeholder, Placeholder, Unclassifiable	42						
OAXA	Non-Renewal (FSZ), One Dwelling, Placeholder, Almonds	42	1			1		

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_ flag
OAXG	Non-Renewal (FSZ), One Dwelling, Placeholder, Grapes	42	1			1		
OAXR	Non-Renewal (FSZ), One Dwelling, Placeholder, Row Crop	42	1			1		
OB3R	Non-Renewal (FSZ), 2+ Dwellings, Licensed Mo Ho, Row Crop	42	2			1		
OBXE	Non-Renewal (FSZ), 2+ Dwellings, Placeholder, Dairy	42	2			1		
OXXA	Non-Renewal (FSZ), Placeholder, Placeholder, Almonds	42						
OXXG	Non-Renewal (FSZ), Placeholder, Placeholder, Grapes	42						
OXXR	Non-Renewal (FSZ), Placeholder, Placeholder, Row Crop	42						
OXXZ	Non-Renewal (FSZ), Placeholder, Placeholder, Unclassifiable	42						
P8XR	Ag Preserve, Sec 11, Placeholder, Row Crop	42						
P8XX	Ag Preserve, Sec 11, Placeholder, Placeholders	42						
GZXX		32						
GZZX		32						
PA3Q	Ag Preserve, One Dwelling, Licensed Mo Ho, Peaches	42	1			1		
PA4A	Ag Preserve, One Dwelling, Unsec Mo Ho, Almonds	42	1			1		
PAFA	Ag Preserve, One Dwelling, Food Processing, Almonds	42	1			1		
PAN5	Ag Preserve, One Dwelling, Nursery/Flower/GrHs, Pool	42	1			1		

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
PAX5	Ag Preserve, One Dwelling, Placeholder, Pool	42	1			1		
PAX8	Ag Preserve, One Dwelling, Placeholder, Prunes	42	1			1		
PAXA	Ag Preserve, One Dwelling, Placeholder, Almonds	42	1			1		
PAXE	Ag Preserve, One Dwelling, Placeholder, Dairy	42	1			1		
PAXF	Ag Preserve, One Dwelling, Placeholder, Figs	42	1			1		
PAXG	Ag Preserve, One Dwelling, Placeholder, Grapes	42	1			1		
PAXI	Ag Preserve, One Dwelling, Placeholder, Irrigated Pasture	42	1			1		
PAXJ	Ag Preserve, One Dwelling, Placeholder, Grazing	42	1			1		
PAXP	Ag Preserve, One Dwelling, Placeholder, Pistachios	42	1			1		
PAXQ	Ag Preserve, One Dwelling, Placeholder, Peaches	42	1			1		
PAXR	Ag Preserve, One Dwelling, Placeholder, Row Crop	42	1			1		
PAXS	Ag Preserve, One Dwelling, Placeholder, Pomegranates	42	1			1		
PAXX	Ag Preserve, One Dwelling, Placeholder, Placeholders	42	1			1		
PAXZ	Ag Preserve, One Dwelling, Placeholder, Unclassifiable	42	1			1		
PB3A	Ag Preserve, 2+ Dwellings, Licensed Mo Ho, Almonds	42	2			1		

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_flag**
PB3E	Ag Preserve, 2+ Dwellings, Licensed Mo Ho, Dairy	42	2			1		
PB3G	Ag Preserve, 2+ Dwellings, Licensed Mo Ho, Grapes	42	2			1		
PB3J	Ag Preserve, 2+ Dwellings, Licensed Mo Ho, Grazing	42	2			1		
PB3R	Ag Preserve, 2+ Dwellings, Licensed Mo Ho, Row Crop	42	2			1		
PB3W	Ag Preserve, 2+ Dwellings, Licensed Mo Ho, Walnuts	42	2			1		
PB3X	Ag Preserve, 2+ Dwellings, Licensed Mo Ho, Placeholders	42	2			1		
PB3Z	Ag Preserve, 2+ Dwellings, Licensed Mo Ho, Unclassifiable	42	2			1		
PB4A	Ag Preserve, 2+ Dwellings, Unsec Mo Ho, Almonds	42	2			1		
PB4E	Ag Preserve, 2+ Dwellings, Unsec Mo Ho, Dairy	42	2			1		
PB4G	Ag Preserve, 2+ Dwellings, Unsec Mo Ho, Grapes	42	2			1		
PB4J	Ag Preserve, 2+ Dwellings, Unsec Mo Ho, Grazing	42	2			1		
PB4R	Ag Preserve, 2+ Dwellings, Unsec Mo Ho, Row Crop	42	2			1		
PB56	Ag Preserve, 2+ Dwellings, Secured Mo Ho, Permanent Foundation	42	2			1		
PB5A	Ag Preserve, 2+ Dwellings, Secured Mo Ho, Almonds	42	2			1		
PB5E	Ag Preserve, 2+ Dwellings, Secured Mo Ho, Dairy	42	2			1		

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
PB5G	Ag Preserve, 2+ Dwellings, Secured Mo Ho, Grapes	42	2			1		
PB5J	Ag Preserve, 2+ Dwellings, Secured Mo Ho, Grazing	42	2			1		
PB5R	Ag Preserve, 2+ Dwellings, Secured Mo Ho, Row Crop	42	2			1		
PB5U	Ag Preserve, 2+ Dwellings, Secured Mo Ho, Commercial Poultry	42	2			1		
PB5X	Ag Preserve, 2+ Dwellings, Secured Mo Ho, Placeholders	42	2			1		
PB5Z	Ag Preserve, 2+ Dwellings, Secured Mo Ho, Unclassifiable	42	2			1		
PBKJ	Ag Preserve, 2+ Dwellings, Mobilehome Park, Grazing	42	2			1		
PBX5	Ag Preserve, 2+ Dwellings, Placeholder, Pool	42	2			1		
PBXA	Ag Preserve, 2+ Dwellings, Placeholder, Almonds	42	2			1		
PBXE	Ag Preserve, 2+ Dwellings, Placeholder, Dairy	42	2			1		
PBXG	Ag Preserve, 2+ Dwellings, Placeholder, Grapes	42	2			1		
PBXI	Ag Preserve, 2+ Dwellings, Placeholder, Irrigated Pasture	42	2			1		
PBXJ	Ag Preserve, 2+ Dwellings, Placeholder, Grazing	42	2			1		
PBXP	Ag Preserve, 2+ Dwellings, Placeholder, Pistachios	42	2			1		
PBXQ	Ag Preserve, 2+ Dwellings, Placeholder, Peaches	42	2			1		

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
PBXR	Ag Preserve, 2+ Dwellings, Placeholder, Row Crop	42	2			1		
PBXS	Ag Preserve, 2+ Dwellings, Placeholder, Pomegranates	42	2			1		
PBXU	Ag Preserve, 2+ Dwellings, Placeholder, Commercial Poultry	42	2			1		
PBXV	Ag Preserve, 2+ Dwellings, Placeholder, Vacant Land	42	2			1		
PBXX	Ag Preserve, 2+ Dwellings, Placeholder, Placeholders	42	2			1		
PBXZ	Ag Preserve, 2+ Dwellings, Placeholder, Unclassifiable	42	2			1		
PBZZ	Ag Preserve, 2+ Dwellings, Unclassifiable, Unclassifiable	42	2			1		
PDAM	Ag Preserve, Triplex, Auto Related, Pecans	42	3					
PDIG	Ag Preserve, Triplex, Farm Labor Camp, Grapes	42	3					
PEXE	Ag Preserve, Fourplex, Placeholder, Dairy	42	4					
PFIG	Ag Preserve, 5-15 Units, Farm Labor Camp, Grapes	42						1
PFZZ	Ag Preserve, 5-15 Units, Unclassifiable, Unclassifiable	42						1
PIWG	Ag Preserve, Industrial Park, Winery, Grapes	42						
PM38	Ag Preserve, One Mobile Home, Licensed Mo Ho, Prunes	42						
PM3A	Ag Preserve, One Mobile Home, Licensed Mo Ho, Almonds	42	1			1		

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
PM3F	Ag Preserve, One Mobile Home, Licensed Mo Ho, Figs	42						
PM3G	Ag Preserve, One Mobile Home, Licensed Mo Ho, Grapes	42	1			1		
PM3I	Ag Preserve, One Mobile Home, Licensed Mo Ho, Irrigated Pasture	42						
PM3J	Ag Preserve, One Mobile Home, Licensed Mo Ho, Grazing	42	1			1		
PM3R	Ag Preserve, One Mobile Home, Licensed Mo Ho, Row Crop	42	1			1		
PM4A	Ag Preserve, One Mobile Home, Unsec Mo Ho, Almonds	42	1			1		
PM4D	Ag Preserve, One Mobile Home, Unsec Mo Ho, Dry Farm	42						
PM4J	Ag Preserve, One Mobile Home, Unsec Mo Ho, Grazing	42	1			1		
PM4R	Ag Preserve, One Mobile Home, Unsec Mo Ho, Row Crop	42						
PM56	Ag Preserve, One Mobile Home, Secured Mo Ho, Permanent Foundation	42	1			1		
PM5A	Ag Preserve, One Mobile Home, Secured Mo Ho, Almonds	42	1			1		
PM5G	Ag Preserve, One Mobile Home, Secured Mo Ho, Grapes	42	1			1		
PM5J	Ag Preserve, One Mobile Home, Secured Mo Ho, Grazing	42	1			1		
PM5P	Ag Preserve, One Mobile Home, Secured Mo Ho, Pistachios	42	1			1		

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
PM5R	Ag Preserve, One Mobile Home, Secured Mo Ho, Row Crop	42	1			1		
IIxx		34						
PM5T	Ag Preserve, One Mobile Home, Secured Mo Ho, Commercial Animal	42	1			1		
PM5W	Ag Preserve, One Mobile Home, Secured Mo Ho, Walnuts	42	1			1		
PM5X	Ag Preserve, One Mobile Home, Secured Mo Ho, Placeholders	42	1			1		
PM5Z	Ag Preserve, One Mobile Home, Secured Mo Ho, Unclassifiable	42	1			1		
PMX6	Ag Preserve, One Mobile Home, Placeholder, Permanent Foundation	42	1			1		
PMXA	Ag Preserve, One Mobile Home, Placeholder, Almonds	42	1			1		
PMXC	Ag Preserve, One Mobile Home, Placeholder, Citrus	42	1			1		
PMXG	Ag Preserve, One Mobile Home, Placeholder, Grapes	42	1			1		
PMXI	Ag Preserve, One Mobile Home, Placeholder, Irrigated Pasture	42	1			1		
PMXJ	Ag Preserve, One Mobile Home, Placeholder, Grazing	42	1			1		
PMXR	Ag Preserve, One Mobile Home, Placeholder, Row Crop	42	1			1		
PN3R	Ag Preserve, 2+ Mo Ho, Licensed Mo Ho, Row Crop	42	2			1		
PN4P	Ag Preserve, 2+ Mo Ho, Unsec Mo Ho, Pistachios	42	2			1		

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
PN5A	Ag Preserve, 2+ Mo Ho, Secured Mo Ho, Almonds	42	2			1		
PN5G	Ag Preserve, 2+ Mo Ho, Secured Mo Ho, Grapes	42	2			1		
PN5P	Ag Preserve, 2+ Mo Ho, Secured Mo Ho, Pistachios	42	2			1		
PN5U	Ag Preserve, 2+ Mo Ho, Secured Mo Ho, Commercial Poultry	42	2			1		
PN5Z	Ag Preserve, 2+ Mo Ho, Secured Mo Ho, Unclassifiable	42	2			1		
PNWZ	Ag Preserve, 2+ Mo Ho, Winery, Unclassifiable	42	2			1		
PNXJ	Ag Preserve, 2+ Mo Ho, Placeholder, Grazing	42	2			1		
POXJ	Ag Preserve, Cabin, Placeholder, Grazing	42	1			1		
POXX	Ag Preserve, Cabin, Placeholder, Placeholders	42	1			1		
PPFJ	Ag Preserve, Misc, Structure, Food Processing, Grazing	42						
PPXA	Ag Preserve, Misc, Structure, Placeholder, Almonds	42						
PPXG	Ag Preserve, Misc, Structure, Placeholder, Grapes	42						
PPXJ	Ag Preserve, Misc, Structure, Placeholder, Grazing	42						
PPXU	Ag Preserve, Misc, Structure, Placeholder, Commercial Poultry	42						
PSAX	Ag Preserve, Stand Alone Building, Auto Related, Placeholders	41						
PSXG	Ag Preserve, Stand Alone Building, Placeholder, Grapes	42						

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_flag**
PSXI	Ag Preserve, Stand Alone Building, Placeholder, Irrigated Pasture	42						
PSXJ	Ag Preserve, Stand Alone Building, Placeholder, Grazing	42						
PSZX	Ag Preserve, Stand Alone Building, Unclassifiable, Placeholders	42						
PUNZ	Ag Preserve, Comm Ofc Complex, Nursery/Flower/GrHs, Unclassifiable	32						
PURL	Ag Preserve, Comm Ofc Complex, Restaurant/Cafe/Bar, Plums	41						
PX5X	Ag Preserve, Placeholder, Secured Mo Ho, Placeholders	42	1			1		
PX7J	Ag Preserve, Placeholder, Conserv Easement, Grazing	42						
PXX7	Ag Preserve, Placeholder, Placeholder, Pears	42						
PXX8	Ag Preserve, Placeholder, Placeholder, Prunes	42						
PXXC	Ag Preserve, Placeholder, Placeholder, Citrus	42						
PXXD	Ag Preserve, Placeholder, Placeholder, Dry Farm	42						
PXXE	Ag Preserve, Placeholder, Placeholder, Dairy	42						
PXXF	Ag Preserve, Placeholder, Placeholder, Figs	42						
PXXG	Ag Preserve, Placeholder, Placeholder, Grapes	42						

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
PXXI	Ag Preserve, Placeholder, Placeholder, Irrigated Pasture	42						
PXXJ	Ag Preserve, Placeholder, Placeholder, Grazing	42						
PXXO	Ag Preserve, Placeholder, Placeholder, Olives	42						
PXXP	Ag Preserve, Placeholder, Placeholder, Pistachios	42						
PXXQ	Ag Preserve, Placeholder, Placeholder, Peaches	42						
PXXR	Ag Preserve, Placeholder, Placeholder, Row Crop	42						
PXXS	Ag Preserve, Placeholder, Placeholder, Pomegranates	42						
PXXW	Ag Preserve, Placeholder, Placeholder, Walnuts	42						
PXXX	Ag Preserve, Placeholder, Placeholder, Placeholders	42						
PXXY	Ag Preserve, Placeholder, Placeholder, Nectarines	42						
PXXZ	Ag Preserve, Placeholder, Placeholder, Unclassifiable	42						
PZ5E	Ag Preserve, Unclassifiable, Secured Mo Ho, Dairy	42						
PZXX	Ag Preserve, Unclassifiable, Placeholder, Placeholders	42						

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
RA4S	Res-SFD-Detached, One Dwelling, Unsec Mo Ho, Pomegranates	42	1			1		
RAAX	Res-SFD-Detached, One Dwelling, Auto Related, Placeholders	41	1			1		
RAFT	Res-SFD-Detached, One Dwelling, Food Processing, Commercial Animal	34	1			1		
RAJX	Res-SFD-Detached, One Dwelling, Medical-Dental, Placeholders	32	1			1		
RAP5	Res-SFD-Detached, One Dwelling, Professional, Pool	32	1			1		
RAPX	Res-SFD-Detached, One Dwelling, Professional, Placeholders	32	1			1		
RAQX	Res-SFD-Detached, One Dwelling, Real Estate Trades, Placeholders	32	1			1		
RARX	Res-SFD-Detached, One Dwelling, Restaurant/Cafe/Bar, Placeholders	41	1			1		
RAXA	Res-SFD-Detached, One Dwelling, Placeholder, Almonds	42	1			1		
RAXB	Res-SFD-Detached, One Dwelling, Placeholder, Apricots	42	1			1		
RAXC	Res-SFD-Detached, One Dwelling, Placeholder, Citrus	42	1			1		
RAXG	Res-SFD-Detached, One Dwelling, Placeholder, Grapes	42	1			1		
RAXI	Res-SFD-Detached, One Dwelling, Placeholder, Irrigated Pasture	42	1			1		
RAXJ	Res-SFD-Detached, One Dwelling, Placeholder, Grazing	42	1			1		

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
RAXM	Res-SFD-Detached, One Dwelling, Placeholder, Pecans	42	1			1		
RAXN	Res-SFD-Detached, One Dwelling, Placeholder, Apples	42	1			1		
RAXP	Res-SFD-Detached, One Dwelling, Placeholder, Pistachios	42	1			1		
RAXQ	Res-SFD-Detached, One Dwelling, Placeholder, Peaches	42	1			1		
RAXR	Res-SFD-Detached, One Dwelling, Placeholder, Row Crop	42	1			1		
RAXU	Res-SFD-Detached, One Dwelling, Placeholder, Commercial Poultry	42	1			1		
RB5A	Res-SFD-Detached, 2+ Dwellings, Secured Mo Ho, Almonds	42	2			1		
RB5J	Res-SFD-Detached, 2+ Dwellings, Secured Mo Ho, Grazing	42	2			1		
RBAX	Res-SFD-Detached, 2+ Dwellings, Auto Related, Placeholders	41	2			1		
RBSX	Res-SFD-Detached, 2+ Dwellings, Supermarket, Placeholders	41	2			1		
IPFZ		34						
IPXJ		42						
RBX4	Res-SFD-Detached, 2+ Dwellings, Placeholder, Retail	41	2			1		
RBXG	Res-SFD-Detached, 2+ Dwellings, Placeholder, Grapes	42	2			1		
RM5A	Res-SFD-Detached, One Mobile Home, Secured Mo Ho, Almonds	42	1			1		

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
RM5J	Res-SFD-Detached, One Mobile Home, Secured Mo Ho, Grazing	42	1			1		
RMS6	Res-SFD-Detached, One Mobile Home, Supermarket, Permanent Foundation	41	1			1		
RMSX	Res-SFD-Detached, One Mobile Home, Supermarket, Placeholders	41	1			1		
RN3J	Res-SFD-Detached, 2+ Mo Ho, Licensed Mo Ho, Grazing	42	2			1		
RN3W	Res-SFD-Detached, 2+ Mo Ho, Licensed Mo Ho, Walnuts	42	2			1		
RN5J	Res-SFD-Detached, 2+ Mo Ho, Secured Mo Ho, Grazing	42	2			1		
RPRX	Res-SFD-Detached, Misc, Structure, Restaurant/Cafe/Bar, Placeholders	41				1		
RRMX	Res-SFD-Detached, , Market, Placeholders	41				1		
RXXA	Res-SFD-Detached, Placeholder, Placeholder, Almonds	42	1			1		
RXXC	Res-SFD-Detached, Placeholder, Placeholder, Citrus	42	1			1		
RXXD	Res-SFD-Detached, Placeholder, Placeholder, Dry Farm	42	1			1		
RXXF	Res-SFD-Detached, Placeholder, Placeholder, Figs	42	1			1		
RXXG	Res-SFD-Detached, Placeholder, Placeholder, Grapes	42	1			1		
RXXJ	Res-SFD-Detached, Placeholder, Placeholder, Grazing	42	1			1		

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
RXXR	Res-SFD-Detached, Placeholder, Placeholder, Row Crop	42	1			1		
RZXD	Res-SFD-Detached, Unclassifiable, Placeholder, Dry Farm	42	1			1		
SCRX	Res-SFD-0 Lot Line, Duplex, Restaurant/Cafe/Bar, Placeholders	41	1				1	
TCX4	Res-Multi-Fam-Apartmt, Duplex, Placeholder, Retail	41	2				1	
TDX4	Res-Multi-Fam-Apartmt, Triplex, Placeholder, Retail	41	3				1	
TEX4	Res-Multi-Fam-Apartmt, Fourplex, Placeholder, Retail	41	4				1	
TEZ4	Res-Multi-Fam-Apartmt, Fourplex, Unclassifiable, Retail	41	4				1	
TGX4	Res-Multi-Fam-Apartmt, 16+ Units, Placeholder, Retail	41					1	1
TGZ4	Res-Multi-Fam-Apartmt, 16+ Units, Unclassifiable, Retail	41					1	1
UXXD	Res-Multi-Condo, Placeholder, Placeholder, Dry Farm	42	1				1	
IIVX		36						
WPR5	Recreational, Misc, Structure, Restaurant/Cafe/Bar, Pool	41						
WPXX	Recreational, Misc, Structure, Placeholder, Placeholders	42						
WPZX	Recreational, Misc, Structure, Unclassifiable, Placeholders	42						
WSRZ	Recreational, Stand Alone Building, Restaurant/Cafe/Bar, Unclassifiable	41						

Madera County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
WSXX	Recreational, Stand Alone Building, Placeholder, Placeholders	42						
WSZX	Recreational, Stand Alone Building, Unclassifiable, Placeholders	42						
WXXX	Recreational, Placeholder, Placeholder, Placeholders	42						
WXZX	Recreational, Placeholder, Unclassifiable, Placeholders	42						
YXXX	Timber Preserve, Placeholder, Placeholder, Placeholders	42						
3B3X		42				1		1
CSHX		38					1	1
DGH5		38					1	1
DPHX		38					1	1
IAEX		34	1			1		
IME3		34	1			1		
KM3X		34	1			1		
NB5R		42				1		1
PA7J		42	1			1		
PAIG		42	1			1		
PAXD		42	1			1		
PBIZ		42				1		1
PLXZ		42					1	1
PX3X		42	1			1		
1214		40						
9999		42						
3AXG		42						
3PZZ		42						
3SZX		42						
3XX		42						

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_ flag
3XZZ		42						
3ZXX		42						
4PVX		36						
4PVZ		36						
4SZX		42						
4XXG		42						
4XXR		42						
5SZZ		42						
5UXX		42						
5ZXX		42						
ASNX		42						
ASXP		42						
AXLJ		42						
AXLX		42						
AXYX		42						
BAEX		34						
BANX		42						
BAYX		42						
BGVG		34						
BQFX		34						
BSEX		34						
BSFR		42						
BXEH		34						
BXFG		42						
BXYX		42						
CACX		41						
CAJX		32						
CAMA		42						
CAQX		32						
Caxx		41						
caxx		41						
CAZ4		41						
CBM4		41						
CBQX		32						
CBRT		41						

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_ flag
CDJX		32						
CMGX		41						
CMN3		36						
CPEZ		34						
CPFW		42						
CPLX		42						
CPNX		41						
CPOX		42						
CRSX		41						
CRXX		41						
CSDX		40						
CSVX		36						
CSW3		41						
CTDX		40						
CTF3		34						
CTP4		40						
CTPZ		40						
CXO4		42						
CXUX		41						
cxxv		41						
CZAX		36						
CZVX		36						
DAO4		42						
DFZX		40						
DPLX		42						
DPPX		32						
DPQX		32						
DPXX		32						
DSCX		41						
DSP4		41						
DSX4		41						
DTAX		36						
DTRZ		41						
DTSZ		40						
DXG4		41						

Madera County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
EAZX		41						
EPZZ		32						
ETZZ		41						
EXXX		32						
FSPZ		32						
ISFX		34						
IUVX		41						
IXMX		42						
IXWX		34						
IXX3		36						
IXXG		42						
IXXO		42						
IXZ3		36						
KIZZ		34						
KMFX		34						
KSAX		34						
KSBZ		36						
ksxx		34						
LXXS		42						
MCXX		42						
MPXX		42						
MXXV		42						
PXLX		42						
PXLZ		42						
PZYX		42						
PZZZ		42						
ZXYX		42						
3AXJ		42						
EEX5		17	4				1	

Table A-10: Merced County Land Use Crosswalk

Merced County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_ flag
101	Residential 1 DU		1			1		
102	Residential 1 DU		1			1		
103	Residential 1 DU		1			1		
104	Residential 1 DU		1			1		
105	Residential 1 DU		1			1		
106	Residential 1 DU		1			1		
107	Residential 1 DU		1			1		
201	Residential 2-4 DU	14					1	1
202	Residential 2-4 DU	14					1	1
203	Residential 2-4 DU	14					1	1
204	Residential 2-4 DU	14					1	1
205	Residential 2-4 DU	14					1	1
206	Residential 2-4 DU	14					1	1
301	Residential 5+ DU	12					1	1
302	Residential 5+ DU	12					1	1
303	Residential 5+ DU	12					1	1
304	Residential 5+ DU	12					1	1
305	Residential 5+ DU	12					1	1
401	Minor Commercial	40						
402	Minor Commercial	40						
403	Minor Commercial	40						
404	Minor Commercial	40						
405	Minor Commercial	40						
406	Minor Commercial	40						
407	Minor Commercial	40						
505	Major Commercial	40						
601	Industrial	34						
604	Industrial	34						
606	Industrial	34						
701	Agriculture	42						
702	Agriculture	42						
704	Agriculture	42						
706	Agriculture	42						
707	Agriculture	42						

Merced County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_
708	Agriculture	42						
711	Agriculture	42						
712	Agriculture	42						
801	Orchard	42						
802	Orchard	42						
804	Orchard	42						
806	Orchard	42						
807	Orchard	42						
808	Orchard	42						
812	Orchard	42						
813	Orchard	42						
814	Orchard	42						
901	Grazing	42						
907	Grazing	42						
909	Grazing	42						
911	Grazing	42						
1001	Vacant							
1002	Vacant							
1003	Vacant							
1004	Vacant							
1005	Vacant							
1006	Vacant							
1007	Vacant							
1010	Vacant							
1012	Vacant							
1020	1020							
1201	Miscellaneous							
1202	Miscellaneous							
1203	Miscellaneous							
1204	Miscellaneous							
1206	Miscellaneous							
1207	Miscellaneous							
1208	Miscellaneous							
1209	Miscellaneous							
1211	Miscellaneous							
1212	Miscellaneous							

Merced County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_
1313	Dairy	42						
1414	Poultry	42						
1515	Government Land							
1616	Utility\Railroad							
1701	Residential 1 DU		1					
1702	Residential 1 DU		1					
1703	Residential 1 DU		1					
1704	Residential 1 DU		1					
1717	Mobile Home Park		1					
1818	Sand & Gravel					1		1
1919	Government Land							
2020	Religious							
4242	Duck Club							
4343	Duck Club							
7070	Industrial	34						

Table A-11: San Joaquin County Land Use Crosswalk

San Joaquin County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_ flag
0	USE CODE NOT ASSIGNED							
1	VAC RES LOT -DEV W/UTIL.							
2	VAC LOT W/PROB. W/C PRECLUDES BLDG A RE							
3	VAC LOT -TOTALLY UNUS. (INCURABLE)							
4	VAC RES LOT W/MICS. RES. IMPRS (GARAGE,							
5	VAC RES SUBDIVISION SITE							
6	VAC RES LOT-UNDEV							
7	POTENTIAL RESIDENTIAL SUBDIVISION							
10	SINGLE FAMILY DWELLING(SFD)		1			1		
11	CONDOMINIUM UNIT		1				1	
12	PLANNED UNIT RESIDENTAIL DEV. (PURD)		1			1		

San Joaquin County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_flag**
13	SINGLE FAMILY RESIDENCE W/ SECONDARY RES SQ FT					1		1
14	SFD W/SECONDARY USE (I.E. BARBER SHOP,	41	1			1		
15	ZERO LOT LINE RES		1				1	
16	RES LOT W/MOBILEHOME		1			1		
17	SINGLE FAMILY with COMMON WALL (DUET,HALF-PLEX,etc)		1				1	
20	VAC LOT (ZONED FOR TWO UNITS)							
21	ONE DUPLEX -ONE BLDG		2				1	
22	TWO SFDS ON SINGLE PARCEL		2			1		
30	VACANT LOT ZONED FOR 3 OR 4 UNITS							
31	SINGLE TRIPLEX -(3 UNITS, 1 STRUC.)		3				1	
32	THREE UNITS -2 OR MORE STRUCTURES		3				1	
34	SINGLE FOURPLEX		4				1	
35	FOUR UNITS, 2 OR MORE STRUCTURES		4				1	
40	VACANT LOTS ZONED FOR APARTMENTS							
41	5-10 RES. UNITS -SINGLE BLDG						1	1
42	5-10 RES. UNITS -2 OR MORE BLDGS.						1	1
43	11-20 RES. UNITS -ONE STRUCTURE						1	1
44	11-20 RES. UNITS -2 OR MORE BLDGS.						1	1
45	21-40 UNITS						1	1
46	41-100 UNITS						1	1
47	OVER 100 UNITS						1	1
48	HIGH RISE APARTMENTS						1	1
50	RURAL RESIDENTIAL -VACANT HOMESITE							
51	RURAL RESIDENCE -1 RES.		1			1		
52	RURAL RESIDENTIAL -2 OR MORE RES.					1		1
53	RURAL RESIDENTIAL -VACANT -DEV. WITH							
54	RURAL RES. -WITH MISC. RES. IMPS; ONLY							

San Joaquin County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
55	LABOR CAMP					1		1
56	RURAL RESIDENTIAL W/MOBILHOME		1			1		
59	RESIDENTIAL CARE HOME (6 UNITS OR LESS)						1	1
60	MOTELS LESS THAN 50 UNITS	38					1	1
61	MOTELS OVER 50 UNITS	38					1	1
62	MOTELS LESS THAN 50 UNITS W/SOME KIT.	38					1	1
63	MOTELS OVER 50 UNITS W/SOME KITCHENS	38					1	1
64	MOTELS LESS THAN 50 UNITS W/SHOPS	38					1	1
65	MOTELS OVER 50 UNITS W/SHOPS	38					1	1
68	RESORT MOTELS -CABINS ETC.	38					1	1
70	HOTEL W/O RESTAURANT	38					1	1
71	HOTEL W/RESTAURANT	38					1	1
78	ROOMING HOUSE -CONVENT -RECTORY ETC.	38					1	1
80	COMMON AREAS -NO STRUCTURES							
81	COMMON AREAS -W/STRUCTURES							
82	COMMON AREAS -ROADS & STREETS							
90	MOBILE HOME PARK					1		1
91	OVERNIGHT TYPE TRAILER PARK					1		1
92	MOBILE HOME PARK W/OVERNIGHT FACILITIES					1		1
93	RESORT TYPE TRAILER PARK					1		1
94	MOBILE HOME CONDOMINIUM LOT		1			1		
95	MOBILEHOME APPURTENANCES							
96	MOBILE HOME		1			1		
100	VACANT COMMERICAL LAND -UNDEV.							
101	VACANT COMMERCIAL LAND W/UTIL.							
102	VACANT COMMERCIAL LAND W/MISC IMPS							
107	POTENTIAL COMMERICAL SUBDIVISION							

San Joaquin County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_ flag
110	SINGLE STORY	41						
111	MULTIPLE STORY STORIES	28						
112	MULTIPLE STORES IN ONE BUILDING	41						
113	STORE WITH RES. UNIT OR UNITS	7					1	1
114	STORE CONDO	41						
120	1 STORE & 1 OFFICE	40						
121	MULTIPLE COMBINATION OF OFFICES, SHOPS,	40						
130	1 STORY DEPARTMENT STORE	41						
131	2 STORY DEPARTMENT STORE	40						
140	GROCERY STORE	41						
141	SUPERMARKETS	41						
142	CONVENIENCE STORE	41						
143	CONVENIENCE STORE WITH GAS SALES	41						
144	FRUIT STAND	41						
150	REGIONAL SHOPPING CENTER	41						
151	COMMUNITY SHOPPING CENTER	41						
152	NEIGHBORHOOD SHOPPING CENTER	41						
153	INDIVIDUAL PARCEL WITHIN REGIONAL SHOPP	40						
154	INDIVIDUAL PARCEL WITHIN COMMUNITY CEN	40						
155	INDIVIDUAL PARCEL W/IN NEIGHBORHOOD SHO	40						
156	SHOPPING CENTER COMMON AREA							
170	1 STORY OFFICE BUILDING	32						
171	2 STORY OFFICE BUILDING	31						
172	3 OR MORE STORY OFFICE BLDG.	31						
173	OFFICE BLDG W/RES UNIT OR UNITS	32					1	1
180	ASSISTED LIVING RESIDENCE						1	1
181	CONGREGATE SENIORS HOUSING						1	1
182	CONTINUING CARE RETIREMENT COMMUNITY						1	1
183	SKILLED NURSING FACILITY						1	1

San Joaquin County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
184	SPECIALTY HOME (DEVELOPMENTALLY DISABLE)						1	1
190	MEDICAL OFFICES	31						
191	DENTAL OFFICES	31						
192	MEDICAL DENTAL COMPLEX	31						
193	VETERINARY HOSPITALS	41						
194	ONE STORY OFFICE CONDO.	31						
195	TWO STORY OFFICE CONDO.	30						
196	MEDICAL OFFICE CONDO.	1					1	1
197	DENTAL OFFICE CONDO.	1					1	1
200	COMMERCIAL COMMON AREA - NON SHOPPING C							
201	MISC. MULTIPLE USES -NONE FULLY DOMINA	41					1	1
202	COMMERCIAL USE(DOES'NT REASONABLY FIT A	42						
203	ANIMAL TRAINING FACILITY	42						
204	DAY CARE CENTER	32						
210	RESTAURANTS	41						
211	FAST FOOD RESTAURANTS	41						
212	FOOD PREPARATION -TAKE OUT ONLY	41						
213	COCKTAIL LOUNGE -BARS	28						
214	RESTAURANT W/RES UNIT OR UNITS	41					1	1
230	WALK-IN THEATERS	28						
231	MULTIPLE SCREEN THEATERS	41						
240	BANKS	41						
250	FULL SERVICE STATIONS	41						
251	SELF SERV. STATION(HAS NO FACILITIES FO	41						
252	SERVICE STATION W/CAR WASH	41						
253	TRUCK TERMINALS	34						
254	BULK PLANTS	34						
255	SELF SERVICE STATION W/MINI MART	41						
256	CONVENIENCE STORE (MINI-MART) W/ GAS SA	41						
260	AUTO SALES W/SERVICE CENTER	41						
261	AUTO SALES W/O SERVICE	41						

San Joaquin County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_ flag
	CENTER							
262	USED CAR LOT	41						
263	OTHER SALES CENTERS (TRAILERS, MOBILE H	41						
270	FARM OR CONTS. MACH. SALES & SERVICE	41						
271	FARM OR CONTS. MACH. SALES ONLY	41						
272	FARM OR CONST. MACH. SERVICE ONLY	41						
280	AUTO & TRUCK REPAIRS & ACCESSORIES	41						
281	SPECIALTY SHOPS (TIRES, BRAKES, ETC.)	41						
282	CAR WASH	41						
283	SELF SERVICE CAR WASH	41						
284	LAUNDRY	41						
285	AUTO BODY SHOP	41						
290	RETAIL NURSERY	42						
291	COMMERCIAL/WHOLESALE NURSERY	42						
300	VACANT INDUSTRIAL LAND UNDEVELOPED							
301	VACANT INDUSTRIAL LAND - DEVELOPED WITH							
302	VACANT INDUSTRIAL LAND W/MISC IMPS							
307	POTENTIAL INDUSTRIAL SUBDIVISION							
310	LIGHT MFG. & LIGHT INDUSTRIAL	34						
311	LIGHT INDUSTRIAL & WAREHOUSING	34						
312	LIGHT INDUSTRIAL WHSE MULTIPLE TENNANTS	34						
313	INDUSTRIAL CONDO	34						
314	SHOP-WORK AREA W/SMALL OFFICE	34						
320	WAREHOUSING -ACTIVE	36						
321	WAREHOUSING -INACTIVE	36						
323	WAREHOUSING -YARD	36						
324	MINI STORAGE WAREHOUSING	36						

San Joaquin County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
330	LUMBER MILLS	34						
331	RETAIL LUMBER YARDS	41						
332	SPECIALTY LUMBER PRODUCTS(MOULDINGS, SA	41						
340	PACKING PLANTS	34						
341	COLD STORAGE OR REFRIGERATED WHSE	36						
350	FRUIT & VEGETABLE	34						
351	MEAT PRODUCTS	34						
352	LARGE WINERY	41						
353	SMALL/BOUTIQUE WINERY	41						
355	OTHER FOOD PROCESSING	34						
360	FEED & GRAIN MILLS	34						
361	RETAIL FEED & GRAIN SALES	41						
362	STOCKYARDS	42						
363	AG CHEMICAL SALES AND/OR APPLICATION	41						
370	HEAVY INDUSTRY	33						
371	SHIPYARD	34						
380	MINERAL PROCESSING	42						
381	SAND & GRAVEL -SHALE	42						
390	INDUSTRIAL COMMON AREA							
391	MISC. INDUSTRIAL MULT. USES - NONE FULL	34						
392	INDUST. USE(DOES'NT REASONABLY FIT ANY	34						
393	AIRPORT(PRIVATE	42						
400	IRRIGATED ORCHARD	42						
401	IRRIGATED ORCHARD W/RESIDENCE	42	1			1		
410		42						
420	IRRIGATED VINEYARD	42						
421	IRRIGATED VINEYARD W/RESIDENCE	42	1			1		
450	IRRIGATED ROW CROPS	42						
451	IRRIGATED ROW CROPS W/RESIDENCE	42	1			1		
460	IRRIGATED PASTURE	42						
461	IRRIGATED PASTURE W/RESIDENCE	42	1			1		

San Joaquin County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
462	HORSE RANCH	42						
463	HORSE RANCH W/RESIDENCE	42	1			1		
470	DAIRY	42						
471	DAIRY W/RESIDENCE	42	1			1		
480	POULTRY RANCH	42						
481	POULTRY RANCH W/RESIDENCE	42	1			1		
490	FEED LOTS	42						
500	DRY FARM	42						
501	DRY FARM W/RESIDENCE	42	1			1		
510	DRY GRAZE	42						
511	DRY GRAZE W/RESIDENCE	42	1			1		
520	NON-IRRIGATED VINEYARDS	42						
521	NON-IRRIGATED VINEYARDS W/RESIDENCE	42	1			1		
530	SPECIALTY FARMS	42						
550	TREE FARM	42						
551	TREE FARM (W/ OR W/O RESIDENCE)	42						1
590	WASTE LANDS							
591	BERMS							
610	SWIM CENTERS	41						
611	RECREATOPMAL CENTERS	41						
612	MARINA OR YACHTING CLUB	42						
613	RAQUETBALL CLUB	41						
614	TENNIS CLUB	41						
615	PRIVATE CAMPGROUND OR RESORT	42						
620	PRIVATELY OWNED DANCE HALLS	41						
630	BOWLING ALLEYS	41						
631	ARCADES & AMUSEMENT CENTERS	41						
632	SKATING RINK	41						
640	CLUBS, LODGE HALLS	59						
650	PRIVATELY OWNED AUDITORIUMS & STADIUMS	34						
660	18 HOLE PUBLIC GOLF COURSE	42						
661	9 HOLE PUBLIC GOLF COURSE	42						

San Joaquin County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
662	COUNTRY CLUB	42						
664	DRIVING RANGE	42						
670	PRIVATELY OWNED RACE TRACKS	42						
680	NON-PROFIT ORG. CAMPS (BOY SCOUTS,ETC.)	42						
690	PRIVATELY OWNED PARKS	42						
710	CHURCH, SYNAGOGUE OR TEMPLE	59						
711	OTHER CHURCH PROPERTY							
720	PRIVATE SCHOOL	47						
721	PAROCHIAL SCHOOL	47						
722	SPECIAL SCHOOL	47						
730	PRIVATE COLLEGES	44						
740	FULL SERVICE HOSPITAL	45						
742	CLINIC	45						
760	ORPHANAGES						1	1
770	CEMETERIES (NON-PROFIT)	42						
771	MORTUARIES & FUNERAL HOMES	59						
772	CEMETARY TAXABLE (PROFIT)	42						
780	VOLUNTEER FIRE DEPTS.							
810	SBE VALUED							
811	UTILITY WATER COMPANY	42						
812	MUTUAL WATER COMPANY	42						
813	CABLE T.V.	42						
814	RADIO & TV BROADCAST SITE	42						
815	PIPELINE RIGHT-OF-WAY							
850	RIGHT-OF-WAY							
851	PRIVATE ROAD							
860	WELL SITE							
861	TANK SITE							
862	SPRINGS & OTHER WATER SOURCES							
870	RIVERS & LAKES							
890	PARKING LOTS -FEE							
891	PARKING LOTS -NO FEE							
892	PARKING GARAGES	29						

San Joaquin County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
900	VACANT FEDERAL LANDS							
901	FEDERAL BUILDINGS	32						
902	MILITARY INSTALLATION	32						
903	MISC FEDERAL PROPERTY							
910	VACANT STATE LANDS							
911	STATE BUILDINGS	32						
913	STATE PARKS & OTHER REC FACILITIES	42						
914	STATE SCHOOLS, COLLEGES	44						
916	MISC STATE PROPERTY	42						
920	VACANT COUNTY LAND							
921	COUNTY BUILDINGS	32						
923	COUNTY PARKS & OTHER REC FACILITIES	42						
924	COUNTY HOSPITALS	45						
925	MISC COUNTY PROPERTY	42						
930	VACANT CITY LANDS							
931	CITY BUILDINGS	32						
932	CITY SHOPS & YARD	34						
933	CITY PARKS & OTHER REC. FACILITIES	42						
934	MUNI. UTILITY PROP.(RESERVOIRS,SEWER PL	42						
935	PARKING LOTS -GARAGES	30						
936	MUNICIPAL AIRPORTS	42						
937	MISC CITY PROPERTY	42						
940	SCHOOL DISTRICT PROPERTIES	42						
941	FIRE DISTRICTS	42						
942	FLOOD CONTROL DISTRICT PROPERTY	42						
943	WATER DISTRICT PROPERTY	42						
944	MISC. DISTRICT PROPERTY	42						
950	PUBLIC OWNED LAND -NON-TAXABLE							
951	PUBLIC OWNED LAND -TAXABLE [Section 11]							

Table A-12: Stanislaus County Land Use Crosswalk

Stanislaus County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
10								
20								1
30								
40								
50								
60								
90								
101			1			1		
111			1			1		
121						1		1
131			1			1		
190								
191			1			1		
201							1	1
211							1	1
221			6				1	
231			15				1	
291			1			1		
300								
310								
320								1
330								
340								
360								
390								
491			1			1		
900								
906								
910			1			1		
920							1	1
930								
990								
70		42						
75		42						

Stanislaus County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
76		42						
80		42						
122		42				1		1
141		41	1			1		
160		34	1			1		
161		34	1			1		
170		42	1			1		
171		42	1			1		
181		42	1			1		
241		41					1	1
261		34	2			1		
262		42	1			1		
270		42	1			1		
271		42	1			1		
272		42	1			1		
273		42	1			1		
274		42	1			1		
275		42	1			1		
277		42	1			1		
281		42	1			1		
290		42	1			1		
370		42						
380		42						
387		42						
400		41						
401		41	1			1		
410		41						
411		41	1			1		
420		41						1
421		41	1			1		
430		41						
431		41	1			1		
440		41						
441		41	1			1		
460		41						

Stanislaus County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
461		41	1			1		
470		41						
471		41	1			1		
480		41						1
481		41	1			1		
490		42						
492		42	1			1		
494		42	1			1		
497		42						
500		41						
501		41	1			1		
510		41						
511		41	1			1		
520		32				1		1
521		32	1			1		
522		32	1			1		
530		38					1	1
531		38					1	1
540		41						
541		41	1			1		
560		32						
561		32	1			1		
570		42						
571		42	1			1		
580		42						
581		42	1			1		
584		42	1			1		
586		42						
587		42						
590		41						
591		41	1			1		
592		41	1			1		
595		42						
596		41						
600		34						

Stanislaus County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
601		34	1			1		
610		36						
611		36	1			1		
612		36	1			1		
620		36						1
621		36	1			1		
630		36						
631		36	1			1		
640		34						
641		34	1			1		
660		33						
661		34	1			1		
662		34	1			1		
664		34	1			1		
670		42						
671		42	1			1		
674		42	1			1		
680		42						
681		42	1			1		
686		42						
690		34						
691		34	1			1		
692		34	1			1		
695		34						
696		34						
700		42						
706		42						
707		42						
710		42						
711		42	1			1		
712		42	1			1		
713		42	1			1		
714		42	1			1		
720		42						1
721		42	1			1		

Stanislaus County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
722		42	1			1		
723		42	1			1		
724		42	1			1		
726		42	1			1		
727		42	1			1		
730		42						
731		42	1			1		
734		42	1			1		
736		42						
740		42						
741		42	1			1		
742		42				1		
743		42	1			1		
744		42	1			1		
746		42						
747		42						
762		42	1			1		
763		42	1			1		
765		42						
767		42						
770		42						
771		42	1			1		
772		42	1			1		
773		42	1			1		
774		42	1			1		
776		42						
781		42	1			1		
783		42	1			1		
784		42	1			1		
786		42						
793		42	1			1		
794		42	1			1		
796		42						
797		42						
802		42	1			1		

Stanislaus County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
803		42	1			1		
805		42						
807		42						
812		42	1			1		
813		42	1			1		
815		42						
817		42						
822		42	1			1		
823		42	1			1		
825		42	1			1		
827		42	1			1		
832		42	1			1		
833		42	1			1		
835		42						
837		42						
842		42	1			1		
843		42	1			1		
845		42						
847		42						
862		42	1			1		
863		42	1			1		
865		42						
867		42						
870		42						
871		42	1			1		
872		42	1			1		
873		42	1			1		
874		42	1			1		
876		42						
880		42						
881		42	1			1		
882		42	1			1		
883		42	1			1		
884		42	1			1		
885		42						

Stanislaus County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
886		42						
887		42						
890		42						
891		42	1			1		
892		42	1			1		
893		42	1			1		
894		42	1			1		
895		42						
896		42						
897		42						
940		41						
941		41	1			1		
950		41						
960		34						1
961		34	1			1		
970		42						
980		42						

Table A-13: Tulare County Land Use Crosswalk

Tulare County Land Use Crosswalk								
LU_Code	description	bt_id	du	min_du	max_du	sf_flag	mf_flag	du_iterate_flag
1			1			1		
100			1			1		
1000								
1002								
1040								
1100			1			1		
1101			1			1		
1102			2			1		
1120			2			1		
1130			3			1		
1140			4			1		
1150			5			1		

Tulare County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
1160			6			1		
1170			7			1		
1180			8			1		
1190			9			1		
11OO			1			1		
1200			2				1	
1220								
1300			3				1	
1320			3				1	
1400			4				1	
1600							1	1
1601							1	1
1610								
1700			1			1		
1710			2			1		
1720			2			1		
1730								
1800			1			1		
1820			2			1		
1830			3			1		
1900			1			1		
1955								
2000								
4900								
5300						1		1
8900								
9000								
9100								
9200								
9400								
9562								
9700								
1500		13					1	1
300		42						
600		42						

Tulare County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
2100		41						
2110		41						
2120		41						
2200		40						
2210		41						
2300		41						
2400		41						
2410		41						
2500		41						
2580		41						
2600		41						
2700		38					1	1
2750		38					1	1
2800		17				1		1
2900		41						
2940		41						
3000		42						
3100		32						
3110		32						
3120		32						
3160		32						
3200		41						
3300		41						
3400		42						
3500		36						
3600		34						
3700		36						
3800		42						
3900		32						
3911		32						
3938		32						
4000		34						
41		34						
4100		34						
4200		33						

Tulare County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_ flag**
4300		42						
4400		34						
4402		34						
4500		42						
4600		42						
4700		34						
4800		34						
5100		42						
5400		42						
5200		42					1	1
6000		42						
6100		42						
6200		42						
630		42						
6300		42						
6400		42						
6500		42						
6600		42						
6700		42						
6800		42						
690		42						
6900		42						
7000		42						
7100		42						
7110		42						
7120		42						
7130		42						
7140		42						
7150		42						
7160		42						
7200		42						
7300		42						
7400		42						
7500		42						
7600		42						

Tulare County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_flag**
7700		42						
7800		42						
7900		42						
8		45						
800		45						
8000		45						
8100		59						
8200		45						
8300		42						
8400		49						
8410		49						
8500		45						
8600		42						
8700		32						
8800		32						
9500		42						
9600		42						
9800		42						
9801		42						
9900		42						

Tulare County Land Use Crosswalk								
LU_Code	**description**	**bt_id**	**du**	**min_du**	**max_du**	**sf_flag**	**mf_flag**	**du_iterate_flag**
7700		42						
7800		42						
7900		42						
8		45						
800		45						
8000		45						
8100		59						
8200		45						
8300		42						
8400		49						
8410		49						
8500		45						
8600		42						
8700		32						
8800		32						
9500		42						
9600		42						
9800		42						
9801		42						
9900		42						

APPENDIX B
Six-Region Study for MXD Travel Model

Traffic Generated by Mixed-Use Developments—Six-Region Study Using Consistent Built Environmental Measures

Reid Ewing[1]; Michael Greenwald[2]; Ming Zhang[3]; Jerry Walters[4]; Mark Feldman[5]; Robert Cervero[6]; Lawrence Frank[7]; and John Thomas[8]

Abstract: Current methods of traffic impact analysis, which rely on rates and adjustments from the Institute of Transportation Engineers, are believed to understate the traffic benefits of mixed-use developments (MXDs), leading to higher exactions and development fees than necessary and discouraging otherwise desirable developments. The purpose of this study is to create new methodology for more accurately predicting the traffic impacts of MXDs. Standard protocols were used to identify and generate data sets for MXDs in six large and diverse metropolitan regions. Data from household travel surveys and geographic information system (GIS) databases were pooled for these MXDs, and travel and built environmental variables were consistently defined across regions. Hierarchical modeling was used to estimate models for internal capture of trips within MXDs, walking and transit use on external trips, and trip length for external automobile trips. MXDs with diverse activities on-site are shown to capture a large share of trips internally, reducing their traffic impacts relative to conventional suburban developments. Smaller MXDs in walkable areas with good transit access generate significant shares of walk and transit trips, thus also mitigating traffic impacts. Centrally located MXDs, small and large, generate shorter vehicle trips, which reduces their impacts relative to outlying developments. **DOI:** 10.1061/(ASCE)UP.1943-5444.0000068.

CE Database subject headings: Traffic management; Assessment; Environmental issues.

Author keywords: Mixed-use development; Trip generation; Internal capture; Traffic impact assessment.

Introduction

Mixed-use development (MXD) is a signature feature of smart growth, New Urbanism, and other contemporary land-use movements aimed at reducing the private automobile's dominance in suburban America. By putting offices, shops, restaurants, residences, and other codependent activities in close proximity to each other, MXD shortens trips and thus allows what might otherwise be external car trips to become internal walk, bike, or transit trips. This in turn can reduce the vehicle miles generated by an MXD relative to what it would be if the same activities were separated in single-use developments. Fewer vehicle miles traveled (VMT) not only relieves traffic congestion but also reduces greenhouse gas (GHG) emissions, air pollution, and fuel consumption. MXDs are also promoted for their supply side benefits, such as possibilities for shared parking and economizing on roadway and related infrastructure expenditures (because peak travel periods often differ between offices, retail, and other uses, enabling investments to be descaled) (Cervero 1988).

A diverse group of stakeholders has a vested interest in the traffic impacts of MXDs. The replacement of off-site car trips with on-site walking or cycling or (for larger mixed-use sites) on-site transit or driving matters to developers who want smooth-flowing traffic conditions to help market their projects, to communities that want to keep existing residents safe from traffic impacts, and to traffic engineers whose very profession is devoted to facilitating traffic flows but often harbor some skepticism about the traffic benefits of MXDs.

Accurately estimating the proportion of trips captured internally by MXDs is vitally important if communities are to accurately assess their traffic impacts and reward such projects through lower exactions and development fees or expedited project approvals. However, lacking a reliable methodology for adjusting trip generation estimates, communities face a dilemma when assessing MXD proposals: do they err on the conservative side by downplaying internal capture and thereby potentially discourage worthwhile projects, or err on the liberal side and risk unmitigated traffic

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impacts? Often, the "do no harm" sentiment prevails: when in doubt, go with conventional practices, which, with MXD proposals, typically means only a small downward adjustment in estimated trips, if any adjustment at all.

In addition to getting internal capture estimates right, accurate assessments of MXD projects also depend on estimating the share of external trips served by alternative modes (e.g., transit and walking). These must also be subtracted from nominal trip generation rates to estimate the net impacts of MXDs on traffic and VMT.

Community acceptance depends on whether a proposed MXD is perceived as a good neighbor. Exaggerated estimates of a project's traffic generation can heighten concerns about congestion, community image and character, and even public health and safety. A nimby backlash can add substantially to the time and expense of securing project approval, and can result in the project being scaled back to a level at which elected officials feel that the trip generation is more acceptable. However, the market demand for the development that is disallowed does not vanish and more often than not ends up in another location, often at a lower density and in a less mixed-use configuration. The end result can be more traffic and higher overall VMT than if the original MXD proposal had been approved.

Traffic generation estimates have supply-side impacts, affecting project design and cost. This includes the most obvious components, such as street widths, parking supply, and access point design, and secondary effects on the design and cost of ancillary infrastructure like storm water drainage systems. Within constrained sites, overdesign of traffic elements can limit the space available for revenue-producing land uses and increase other development costs; forcing, for example, the rerouting of utilities to accommodate traffic-handling infrastructure.

Statutory laws also place pressure on getting the traffic estimates for MXDs right. The formal National Environmental Policy Act (NEPA) process and state-level environmental reviews rely on traffic generation estimates to assess impacts and dictate a project's mitigation measures. Estimates that exaggerate negative impacts increase the likelihood a project will be judged as a significant threat to environmental quality. This leads to more rigorous analysis and reporting of a wide array of potential secondary impacts, such as the growth inducing effects of the additional required traffic capacity. It also prompts a more protracted discussion of community concerns through formal public involvement, document review, comment/response periods, and certification protocols. In addition, it can incorrectly trigger a review of other impacts such as noise, air quality, energy use, and greenhouse gas emissions.

Development fee programs rely heavily on traffic generation estimates. As the most comprehensive and widely used reference on the subject, the *Trip Generation* report of the Institute of Transportation Engineers (ITE) (2008) has become the principal data source for setting transportation development fee rates. Most cities, counties, and regional agencies opt for uniformity rather than accuracy in this regard. In the interest of standardization of assumptions and approach, many jurisdictions rely on the numbers in *Trip Generation* to quantify traffic impacts and mitigation fee schedules. The unquestioning use of the ITE report can unreasonably jeopardize a MXD project's approval, financial feasibility, and design quality.

Conventional Traffic Impact Analysis

Virtually all traffic impact analyses rely on the ITE *Trip Generation* report (2008). The ITE rates are largely representative of individual, single-use suburban developments whose trips are by private vehicle and whose origins or destinations lie outside the development. Quoting the report: "Data were primarily collected at suburban localities with little or no transit service, nearby pedestrian amenities, or travel demand management (TDM) programs." Recognizing but not resolving this limitation, *Trip Generation* advises: "At specific sites, the user may want to modify the trip generation rates presented in this document to reflect the presence of public transportation service, ridesharing or other TDM measures, enhanced pedestrian and bicycle trip-making opportunities, or other special characteristics of the site or surrounding area." Unfortunately, the desire among traffic engineers for standardization and substantial documented evidence prevents them from taking this advice in the vast majority of cases.

Even setting aside the variety and complexity of mixed-use developments, the reliability of *Trip Generation* for evaluating simple single-use developments is less than one might assume. For example, for the most widely studied land-use category within the report, single-family residential, the average ITE *Trip Generation* daily rate is 9.6 vehicle trips per dwelling unit, but the standard deviation is 3.7, almost 40% of the mean. Even for this most uniform of land-use types, when described in terms of a single descriptive variable (number of dwelling units), the 9.6 ITE trip generation figure used in impact study guidelines and fee ordinances throughout the United States is just a midpoint in a standard deviation range of 5.9 to 13.3 vehicle trips per dwelling. The standard deviations for other common and well-studied land-use types (e.g., office buildings and shopping centers) are at least $\pm 50\%$ of the mean values. Clearly, trip generation estimation is far from a precise science.

Professor Donald Shoup of UCLA has been particularly critical of *Trip Generation* for the following reasons: the false precision with which average trip generation rates are presented, the small samples upon which average rates and regression equations are based, the insignificance of regression coefficients and constants, the implicit assumption that trip generation increases with building size, and the disregard of factors other than building size in the regression analyses. Pointing to the need to represent land-use interactions more carefully, Shoup remarks, "Floor area is only one among many factors that influence vehicle trips at a site, and we should not expect floor area or any other single variable to accurately predict the number of vehicle trips at any site or land-use" (Shoup 2003).

As an indication of just how far off the mark ITE rates may land, the Transit Cooperative Research Program (TCRP) recently funded a study of the trip generating characteristics of transit-oriented developments (TODs) (Cervero and Arrington 2008). The aim was to seed the ITE *Trip Generation* report with original and reliable trip generation data for one important TOD land-use—housing—with the expectation that other TOD land uses will be added later. For all TOD housing projects studied, weekday vehicle trip rates were considerably below the ITE average rate for similar uses. Taking the weighted average across the 17 case-study projects, TOD housing projects, which included both multifamily and single-family residential units, generated approximately 44% fewer vehicle trips than predicted by the ITE report (3.8 trips per dwelling unit for TOD housing versus 6.7 trips per dwelling unit by ITE estimates for the site-specific mixes of multi- and single-family residences).

ITE Method for MXDs

For mixed-use development projects, Chapter 7 of *Trip Generation Handbook* (2004) outlines a procedure for estimating the proportion of trips that remain within the development (i.e., the internal capture rate), and hence place no strain on the external street network. An ITE member survey found that nearly two-thirds of practitioners estimate internal capture rates using this procedure. The procedure works as follows:

1. The analyst determines the amounts of different land-use types (residential, retail, and office) contained within the development.
2. These amounts are multiplied by ITE's per-unit trip generation rates to obtain a preliminary estimate of the number of vehicle trips generated by the site. This preliminary estimate is what the site would be expected to generate if there were no interactions among the on-site uses.
3. The generated trips are then reduced by a certain percentage to account for internal-capture of trips within MXDs. The reductions are based on lookup tables. The share of internal trips from the appropriate lookup table is multiplied by total numbers of trips generated by a given use to obtain an initial estimate of internal trips for each producing use and attracting use.
4. For each pair of land uses, productions and attractions are reconciled such that the number of internal trips produced by one use just equals the number attracted by the other use. The lesser of the two estimates of internal trips constrains the number of internal trips generated by the other use.

Strengths of the Current ITE Method

From the viewpoint of the practicing engineer, the ITE internal capture methodology has some important advantages:

1. It seems objective. Two analysts given the same data will arrive at exactly the same result. There is no room for negotiation or interpretation (and therefore no reason to pressure the analyst into skewing the results in a predetermined direction).
2. It seems logical. Most engineers readily accept the idea that the degree of internalization will be determined by how well the productions and attractions match for each trip purpose.
3. It is fast. With a spreadsheet template, an analyst can input the data and have an answer in a matter of minutes.

Viewed another way, any new methodology that lacks these qualities may not find wide acceptance within the engineering community.

Weaknesses of the Current Method

The ITE methodology also has major shortcomings:

1. The two lookup tables are based on data for a "limited number of multiuse sites in Florida" (specifically, three sites analyzed by the Florida Department of Transportation, ITE 2004). The accuracy of forecasts is thus dependent on how closely the site being analyzed matches the sites used in the tables' creation. The fact that the data are drawn from the suburbs of Florida casts doubt on the applicability to other parts of the country. The handbook acknowledges this problem and instructs the analyst to find analogous sites locally and collect his own data to produce locally valid lookup tables.
2. The land-use types and adjustments embodied in the lookup tables are limited to the three uses: residential, retail, and offices. The traffic impacts of other mixed uses cannot be assessed.
3. The scale of development is disregarded. Clearly, a large site with many productions and attractions is more likely to produce matches than a small site, and the lookup tables for large sites should have higher cell percentages than the tables for small sites. Development scale was the most significant influence on internal capture rates in a study of South Florida MXDs, and more than half of all trips were found to be internalized by community-scale MXDs, far in excess of any rate obtainable with the handbook method (Ewing et al. 2001).
4. The land-use context of development projects is ignored. Common sense and the literature tell us that projects in remote locations are more likely to capture trips on-site than those surrounded by competing trip attractions. For MXDs in South Florida, the second most important determinant of internal capture rates was accessibility to the rest of the region (second after the scale of development). Conversely, projects in areas of high accessibility are more likely to generate walk trips to external destinations.
5. The possibility of mode shifts for well-integrated, transit-served sites is not explicitly considered. This may not bias results for free-standing sites, but infill projects within an urban context may capture few trips internally but still have significant vehicle trip reductions relative to the ITE rates.
6. The length of external private vehicle trips is not considered. The ITE methodology deals with trip generation, not traffic generation. Clearly, in terms of roadway congestion, emissions, and other impacts, a 10-mile trip has a greater impact than a 5-mile trip. Trip distribution is an ad hoc process under the ITE methodology.

Parallel Efforts

There would seem to be two ways to refine ITE trip generation estimates of MXDs. One, a bottom-up approach, would add to the paltry set of development projects that currently constitute the ITE database on MXDs, analyze in detail this larger sample's trip-making characteristics, and then derive a set of more complete adjustments to ITE trip rates. In an effort parallel to our own, the National Cooperative Highway Research Program (NCHRP) is taking this approach in NCHRP Project 8-51, "Enhancing Internal Trip Capture Estimation for Mixed-Use Developments." Adding four sites to the three that currently form the basis for internal capture calculations in ITE's *Trip Generation Handbook* (2004), the project has developed an estimation procedure that includes a proximity adjustment to account for project size and layout.

A second approach, more top down in nature, would assemble enough data on MXDs to estimate statistical models of traffic generation in terms of standard built environmental variables, the so-called "D" variables of density, diversity, design, destination accessibility, distance to transit, and development scale. Taking this approach, Ewing et al. (2001) modeled internal capture rates for 20 mixed-use communities in South Florida. For the 20 communities, internal capture rates ranged from 0 to 57% of all trip ends generated by the community.

To explain this variation, internal capture rates were modeled in terms of land-use and accessibility measures. The variable that proved most strongly related to internal capture was neither land-use mix nor density, but the size of the community itself. The two communities with the highest internal capture rates, Wellington and Weston, also are the largest, each having more than 30,000 residents and 5,000 jobs. Indeed, these two communities are large enough to have incorporated as their own small cities. The second most important variable was regional accessibility, which was inversely related to internal capture rates. Both of these communities are on the western edge of development in Southeast Florida, far from other population centers.

Owing to size and inaccessibility, these communities capture a much higher percentage of trips internally than, for example, the higher density and better-mixed Miami Lakes. However, Miami

Lakes doubtless generates shorter auto trips and many more walk, bicycle, and transit trips than the other two. Its overall impact on the regional road network is almost certainly less.

The validity and reliability of Ewing et al.'s results are limited by the small sample, limited geography coverage, and small number of built environmental variables. The present study improves on the earlier study by, in this order: (1) pooling travel and built environmental data for 239 MXDs in six diverse regions; (2) consistently defining travel outcomes and built environmental variables for these MXDs and regions; (3) estimating models of internal capture, external walk and transit choice, and external private vehicle trip length using hierarchical modeling methods; and (4) validating the results through comparison to traffic counts at an independent set of mixed-use sites in various parts of the United States.

Conceptual Framework

In travel research, urban development patterns have come to be characterized by "D" variables. The original "three Ds," coined by Cervero and Kockelman (1997), are density, diversity, and design. Additional Ds have been labeled since then: destination accessibility, distance to transit, and demographics (Ewing and Cervero 2001, 2010). An additional D variable is relevant to this analysis: development scale.

The theory of rational consumer choice underlies this study. It is well articulated elsewhere (for example, Crane 1996; Boarnet and Crane 2001; Cervero 2002; Zhang 2004; Cao et al. 2009). Travel to/from MXDs is conceived as a series of choices that depend on the D variables (see conceptual framework in Fig. 1). The choices relate directly to the methodology this paper is proposing to adjust ITE trip generation rates downward.

The first adjustment to ITE rates is for trips that remain within the development. Destination choice is conceived as dichotomous. A traveler may choose a destination within the development, or a destination outside the development. Internal trips are treated as 100% deductions from ITE trip generation rates.

Then, for trips that leave the development, adjustments are made for walking and transit use. Mode choices are conceived as dichotomous. For external trips, a traveler may choose to walk or not. Likewise, the traveler may choose to use transit or not. Walking and transit use may be treated as 100% deductions from ITE trip generation rates, or may be treated as partial offsets. It is reasonable to assume that transit trips substitute for automobile trips, but walk trips may supplement or substitute for automobile trips. The study team plans to propose substitution rates based on a review of literature.

Finally, for external personal vehicle trips, the traveler chooses a destination. This destination may be near or far. This outcome variable is continuous rather than dichotomous.

The D variables in Fig. 1 are characteristics of travelers, MXDs, and regions, as defined in the following. The D variables determine, moderate, mediate, and confound travel decisions.

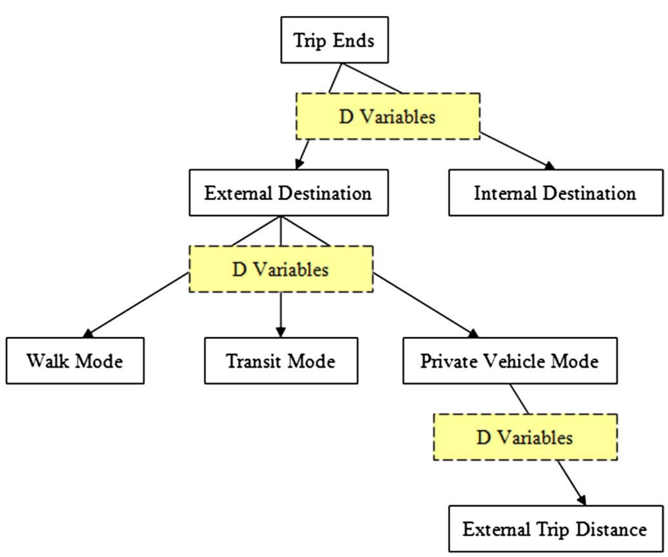

Fig. 1. Traffic impact adjustments

Sample Selection

A main criterion for inclusion of regions in this study was data availability. Regions had to offer:

1. Regional household travel surveys with XY coordinates for trip ends, so we could distinguish trips to, from, and within small MXDs; and
2. Land use databases at the parcel level with detailed land-use classifications, so we could study land-use intensity and mix down to the parcel level.

Most U.S. regions fall short on one or both counts. Although nearly all metropolitan planning organizations (MPOs) have conducted regional household travel surveys as the basis for the calibration of regional travel demand models, most have geocoded trip ends only at the relatively coarse geography of traffic analysis zones. Likewise, although most MPOs have historical land-use databases that are used in model calibration, these too provide data only for the relatively coarse geography of traffic analysis zones. Traffic analysis zones vary in size from region to region, but as a general rule, are equivalent to census block groups. They are large relative to many MXDs, and in any event, will ordinarily not coincide with MXD boundaries.

Thirteen regional household travel databases were identified that met the first criterion. This was narrowed down to six regions based on the availability of parcel-level land-use data and the experience of planning researchers who had worked with these data sets.

All six travel databases were derived from large-scale household travel diary surveys. All allowed the writers to classify trips by purpose and mode of travel. All allowed us to control for socioeconomic characteristics of travelers that may confound interactions between the built environment and travel. All had already been linked to built environmental databases. Although the specific variables differed somewhat from database to database, it was possible to reconcile differences and specify equivalent models. Also, although the years of the surveys differed, it was possible to control for these and other fixed effects at the regional level in a three-level hierarchical model.

Identifying MXDs

The ITE definition of multiuse development was modified to create a generic definition of MXD that would encompass many existing areas with interconnected, mixed land-use patterns:

> "A mixed-use development or district consists of two or more land uses between which trips can be made using local streets, without having to use major streets. The uses may include residential, retail, office, and/or entertainment. There may be walk trips between the uses."

To identify MXDs in the six study regions at the dates of the most recent regional household travel surveys, the team used a bottom-up, expert-based process in which planners for the different localities were queried about MXDs within their boundaries. Using this approach, a definition of an MXD was read to local planners over the phone, and they were asked to name, identify the boundaries, and list the uses contained within such areas. In two of the six regions, local traffic engineers and ITE members were asked to review the selected sites to confirm that they met the criteria normally applied by practitioners to identify mixed-use developments.

Final Samples

A total of 239 MXDs were identified, ranging from a low of 24 in Atlanta to a high of 59 in Boston. Site characteristics ranged from compact infill sites near the region's core to low-rise freeway oriented developments. The 239 survey sites varied in population and employment densities, mix of jobs and housing, presence or absence of transit, and location within the region. The sites ranged in size from less than five acres to over 2,000 acres, and over 15,000 residents and employees.

Sample statistics are shown in Table 1. The regions that contribute modest numbers of trip ends to the sample still add statistical power. The importance of Boston, Houston, and Sacramento lies in the number of MXDs each contributes, not in the number of trip ends. Also, the inclusion of the three regions doubles the number of regions in the sample. In a hierarchical analysis, statistical power is limited by the number of degrees of freedom at each level of analysis. There are ample cases at Level 1, the trip end level, but a shortage of cases at Level 2, the MXD level, and a severe shortage at Level 3, the regional level.

RiverPlace, a classic MXD just south of downtown Portland, is one of the 239 MXDs in our sample (Fig. 2). Its internal capture rate is a surprisingly high 36%. Of the external trips, 14% are made by walking and 9% by transit. Its external auto trips average 7.7 miles. According to the National Household Travel Survey of 2009, 14% of Portland's trips are by walking, and 2% are by transit. The average vehicle trip length in the Portland Consolidated Metropolitan Statistical Area is 8.9 miles. On balance, the traffic impact of RiverPlace is a fraction of the regional average.

Table 1. Sample Statistics

	Survey year	MXDs	Mean acreage per MXD	Total trip ends	Mean trip ends per MXD
Atlanta	2001	24	287	6,167	257
Boston	1991	59	175	3,578	61
Houston	1995	34	401	1,584	47
Portland	1994	53	116	6,146	116
Sacramento	2000	25	179	2,487	99
Seattle	1999	44	207	15,915	362
Total		239	211	35,877	150

Fig. 2. (Color) RiverPlace at eye level

Variables

In this study, all seven types of D variables were measured and used to predict the travel characteristics of MXDs (Tables 2 and 3). The richness of the data sets varies from region to region. Portland and Atlanta have the most complete data sets. Houston and Sacramento have the least complete data sets. Sidewalk data, for example, are only available for Atlanta and Portland. Floor area ratios are only available for Atlanta, Portland, and Seattle. Measures of job mix are only available for Atlanta, Boston, Portland, and Seattle.

To maximize the sample of MXDs, the writers decided to limit our analysis to built environmental variables available for all six regions. This also simplifies the use of the resulting models by practitioners, who may have incomplete data on their projects or their surroundings.

There is great variation in internal capture rates from MXD to MXD and region to region. Across regions, average internal capture rates vary from a low of 15.9% in Portland to a high of 31.1% for Houston (Table 4). The high rate for Houston may reflect the fact that Houston's MXDs are, in general, larger and more remotely located than those in other regions. Many are standalone master-planned communities.

In all household travel surveys, automobile, walk, and transit (bus or rail, where available) are identified as separate modes of travel. Bicycle is as well, but samples are too small to be reliably analyzed. In all regions, the dominant mode for external trips to/from MXDs is the automobile ("private motor vehicle"). The essential choices facing travelers are to walk or use an automobile, or to take transit or use an automobile. For external trips, average mode shares by walking and transit combined vary from a low of 3.3% for Sacramento to a high of 28.4% for Boston (Table 4).

Of the 35,877 trip ends generated by these MXDs, 6,378 (17.8%) involved trips within the mixed-use site, another 2,099 (5.9%) involved trips entering or leaving the site via walking, and another 1,995 (5.6%) involved trips entering or leaving via transit. Thus, on average, a total of 29% of the trip ends generated by mixed-use developments put no strain on the external street network and should be deducted from ITE trip rates for standalone suburban developments.

Trip distances are also variable across regions. For external auto trips, average distances range from 4.6 miles for MXDs in Boston to 13.9 miles for MXDs in Houston (Table 4). Again, this reflects the size and remoteness of Houston's MXDs.

Table 5 provides comparable data for trips internal to MXDs. In four of the six regions, approximately half of the internal trips are walk trips, and auto trips are short. For these regions, it may be reasonable to ignore the contribution of internal trips to regional VMT and emissions, particularly since internal trips are only approximately 16% of all trips produced by or attracted to these MXDs. For the remaining two regions, with their large master-planned communities, the share of walk trips is low, and auto trips are relatively long. For these regions, the contribution of internal trips to regional VMT and emissions is significant. Although these trips may not contribute to area-wide congestion, they should be considered in VMT and emissions calculations.

Table 2. Variable Definition and Description

Outcome variables	Definition
INTERNAL	Dummy variable indicating that a trip remains internal to the MXD ($1 =$ internal, $0 =$ external).
WALK	Dummy variable indicating that the travel mode on an external trip is walking ($1 =$ walk, $0 =$ other).
TRANSIT	Dummy variable indicating that the travel mode on an external trip is public bus or rail ($1 =$ transit, $0 =$ other).
TDIST	Network trip distance between origin and destination locations for an external private vehicle trip, in miles.
Explanatory variables	
	Level 1 traveler/household level
CHILD	Variable indicating that the traveler is under 16 years of age ($1 =$ child, $0 =$ adult).
HHSIZE	Number of members of the household.
VEHCAP	Number of motorized vehicles per person in the household.
BUSSTOP	Dummy variable indicating that the household lives within $1/4$ mile of a bus stop ($1 =$ yes, $0 =$ no)
	Level 2 MXD explanatory variables
AREA	Gross land area of the MXD in square miles.
POP	Resident population within the MXD; prorated sum of the population for the census block groups that intersect the MXD. Prorating was done by calculating density of population per residential acre (tax lots designated single-family or multifamily) for the entire census block group, then multiplying the density by the amount of residential acreage within the block group contributing to the MXD, and finally, summing over all block groups intersecting the MXD area. For Houston, data at the traffic analysis zone (TAZ) level were prorated.
EMP	Employment within the MXD; weighted sum of the employment within the MXD for all Standard Industrial Classification (SIC) industries. For Portland, employment estimates were based on the average number of employees in each size category, summed across employer size categories. For other regions, data at the TAZ level were prorated.
ACTIVITY	Resident population plus employment within the MXD.
ACTDEN	Activity density per square mile within the MXD. Sum of population and employment within the MXD, divided by gross land area.
DEVLAND	Proportion of developed land within the MXD.
JOBPOP	Index that measures balance between employment and resident population within MXD. Index ranges from 0, where only jobs or residents are present in an MXD, not both, to 1 where the ratio of jobs to residents is optimal from the standpoint of trip generation. Values are intermediate when MXDs have both jobs and residents, but one predominates.[a]
LANDMIX	Another diversity index that captures the variety of land uses within the MXD. This is an entropy calculation based on net acreage in land-use categories likely to exchange trips. For Portland, the land uses were: residential, commercial, industrial, and public or semipublic.[b] For other regions, the categories were slightly different.[c] The entropy index varies in value from 0, where all developed land is in one of these categories, to 1, where developed land is evenly divided among these categories.
STRDEN	Centerline miles of all streets per square mile of gross land area within the MXD.
INTDEN	Number of intersections per square mile of gross land area within the MXD.
EMPMILE	Total employment outside the MXD within one mile of the boundary. Weighted average for all TAZs intersecting the MXD. Weighting was done by proportion of each TAZ within the MXD boundary relative to an entire TAZ area (i.e., "clipping" the block group with the MXD polygon).
EMP30T	Share of total regional employment accessible within 30-min travel time of the MXD using transit.
EMP10A, EMP20A, EMP30A	Share of total regional employment accessible within 10, 20, and 30-min travel time of the MXD using an automobile at midday.
STOPDEN	Number of transit stops within the MXD per square mile of land area. Uses 25 ft buffer to catch bus stops on periphery.
RAILSTOP	Rail station located within the MXD ($1 =$ yes, $0 =$ no). Commuter, metro, and light rail systems are all considered.
	Level 3 regional explanatory variables
REGPOP	Population within the region.
REGEMP	Employment within the region.
REGACT	Activity within the region (population $+$ employment).
SPRAWL	Measure of regional sprawl developed by Ewing et al. (2002, 2003). Index derived by extracting the common variance from multiple measures through principal components analysis.

[a] $\text{JOBPOP} = 1 - [\text{ABS}(\text{employment} - 0.2 * \text{population})/(\text{employment} + 0.2 * \text{population})]$; ABS is the absolute value of the expression in parentheses. The value 0.2, representing a balance of employment and population, was found through trial and error to maximize the explanatory power of the variable.

[b] The entropy calculation is $\text{LANDMIX} = -[\text{single-family share} * \text{LN}(\text{single} - \text{family share}) + \text{multifamily share} * \text{LN}(\text{multifamily share}) + \text{commercial share} * \text{LN}(\text{commercial share}) + \text{industrial share} * \text{LN}(\text{industrial share}) + \text{public share} * \text{LN}(\text{public share})]/\text{LN}(5)$, where LN is the natural logarithm.

[c] For Houston, the land uses were: residential, commercial, industrial, and institutional; a mixed residential and commercial class of land uses was included with commercial. For Boston, the land uses were: residential, commercial, industrial, and recreational. For Seattle, detailed land uses were aggregated into four categories: residential, commercial, industrial, and institutional. For Atlanta, detailed land uses were aggregated into four categories: residential, commercial, industrial, and institutional. For Sacramento, detailed land uses were aggregated into four categories: residential, commercial, industrial, and institutional; a mixed class of land uses was included with commercial.

Table 3. Sample Sizes and Descriptive Statistics for Levels 1 and 2 Variables

	N	Mean	SD
INTERNAL	35,877	0.18	0.38
WALK	29,499	0.07	0.26
TRANSIT	29,499	0.07	0.25
TDIST	23,921	6.48	7.79
CHILD	35,877	0.10	0.30
HHSIZE	35,877	2.66	1.32
VEHCAP	35,877	0.80	0.47
BUSSTOP	35,877	0.43	0.50
AREA	239	0.33	0.32
POP	239	2,271	3,261
EMP	239	2,696	5,572
ACTIVITY	239	4,967	6,945
ACTDEN	239	19,780	30,669
DEVLAND	239	0.83	0.22
JOBPOP	239	0.46	0.31
LANDMIX	239	0.52	0.20
STRDEN	239	25.4	10.5
INTDEN	239	257	203
EMPMILE	239	30,510	50,914
EMP30T	239	0.058	0.095
EMP10A	239	0.048	0.073
EMP20A	239	0.185	0.230
EMP30A	239	0.336	0.391
STOPDEN	239	70.8	83.6
RAILSTOP	239	0.08	0.28

Table 4. Average Internal Capture Rates, Walk and Transit Mode Shares for External Trips, and Auto Trip Distances for External Trips to/from MXDs

Region	Internal capture (percentage of all trips)	Mode share percentages for external trips			Auto distance for external trips (miles)
		Walk share	Transit share	Sum of walk and transit	
Atlanta	16.7%	5.0%	3.1%	8.1%	6.3
Boston	16.9%	20.6%	7.8%	28.4%	4.6
Houston	31.1%	3.1%	6.1%	9.3%	13.9
Portland	15.9%	7.3%	4.6%	11.9%	4.8
Sacramento	16.4%	2.9%	0.4%	3.3%	6.8
Seattle	18.0%	5.8%	9.9%	15.7%	6.9
Overall	17.8%	7.1%	6.8%	13.9%	6.5

Table 5. Walk and Transit Mode Shares and Auto Trip Distances for Trips Internal to MXDs

	Walk share of internal trips	Transit share of internal trips	Sum of walk and transit internal trips	Auto distance of internal trips (miles)
Atlanta	53.7%	0.8%	54.5%	0.45
Boston	54.3%	1.0%	55.3%	0.51
Houston	15.0%	4.5%	19.5%	3.29
Portland	43.4%	0.8%	44.2%	0.57
Sacramento	7.4%	0%	7.4%	0.64
Seattle	57.1%	1.1%	58.2%	0.36
Overall	47.7%	1.2%	48.9%	0.81

Models

As indicated, four outcomes are modeled in this study: choice of internal destination, choice of walking on external trips, choice of transit on external trips, and distance of external trips by private vehicle. Models apply to both trips produced by and trips attracted to MXDs. Models are estimated separately by trip purpose: home-based work, home-based other, and non-home-based. The writers presume that different factors might be at play, or that the same factors might be more or less important when people travel for different purposes. Modeling by trip purpose also gives us some ability to distinguish peak hour travel (disproportionately home-based work) from off-peak travel (disproportionately home-based other and non-home-based).

The writers took an exploratory approach in modeling factors that could explain outcome variables, seeking to include at least one variable from each of the six Ds. To keep the results parsimonious and avoid possible multicollinearity problems, the threshold for inclusion of variables in models was a significance level of 0.10. A majority of variables included in our models have much higher significance levels than this threshold value.

For internal capture, our dependent variable is the natural log of the odds of an individual making a trip with both ends within an MXD. For external walk and transit trips, the dependent variable is the natural log of the odds of an individual making a trip by these modes. For external private vehicle trips, the dependent variable is the distance from origin to destination in miles.

For these outcomes, models have been estimated with both linear and logarithmic (natural log) values of the independent variables. The logarithmic models, which express the odds as a power function of the independent variables, outperform the linear models in terms of their pseudo-R^2s, sensitivity to changes in values of independent variables, and validation results (described in the following). Thus, only the logarithmic models are presented in this article. Coefficient values are arc elasticities of odds with respect to the independent variables.

For estimating the trip distance by automobile, models took three forms: linear, semilogarithmic (linear-log), and log-log forms. The semilogarithmic models, which express trip distance as a linear sum of logged variables, outperform the other models in terms of their pseudo-R^2s and sensitivity to changes in values of independent variables. Only the semilogarithmic models are presented in this article.

This study's data and model structure are hierarchical. Thus, hierarchical modeling is the best methodology to account for dependence among observations, in this case the dependence of trips to and from a given MXD and dependence of MXDs within a given region. All the trips to/from a given MXD share the characteristics of the MXD, that is, are dependent on these characteristics. This dependence violates the independence assumption of ordinary least squares (OLS) regression. Standard errors of regression coefficients based on OLS will consequently be underestimated. Moreover, OLS coefficient estimates will be inefficient. Hierarchical (multilevel) modeling overcomes these limitations, accounting for the dependence among observations and producing more accurate coefficient and standard error estimates (Raudenbush and Bryk 2002).

The writers initially conceived the data structure as a five-level hierarchy, with trips nested within individuals, individuals nested within households, households nested within MXDs, and MXDs nested within metropolitan regions. Upon review of the data set, we found that the data are not so neatly hierarchical. Many of the individuals in the sample make trips to or from more than one MXD.

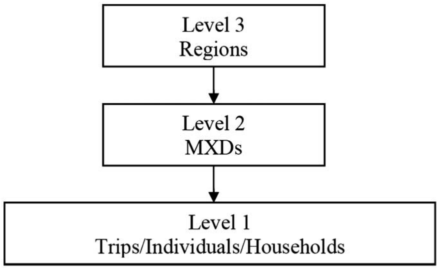

Fig. 3. Data and model structure

This has implications for modeling methodology. Rather than a five-level hierarchy, the choices facing travelers have been modeled in a three-level framework. Individual trip ends are uniquely identified with MXDs. Therefore, trips (their characteristics and the associated characteristics of travelers and their households) form Level 1 in the hierarchy, MXDs form Level 2, and regions form Level 3 (Fig. 3). Within a hierarchical model, each level in the data structure is formally represented by its own submodel. The submodels are statistically linked.

Models were estimated with hierarchical linear and nonlinear modeling (HLM) 6 software. Hierarchical linear models were estimated for the continuous outcome (trip distance), and hierarchical nonlinear models were estimated for the dichotomous outcomes (internal versus external, walk versus other, and transit versus other). Hierarchical linear modeling is analogous to linear regression analysis, although models are estimated by using maximum likelihood estimation rather than OLS. Hierarchical nonlinear modeling is analogous to logistic regression. Like logistic regression, hierarchical nonlinear modeling uses maximum likelihood estimation.

In the initial model estimations, only the intercepts were allowed to randomly vary across higher level units. All of the regression coefficients at higher levels were treated as fixed. These are referred to as random intercept models (Raudenbush and Bryk 2002). As the sample of MXDs expanded, we also tested for cross-level variable interactions with random coefficient models. It is certainly possible that the relationship between, for example, walking and vehicle availability varies with size of the MXD, or the relationship between internal capture and MXD density varies from region to region. As the cross-level interaction terms seldom proved significant, only the random intercept models are presented in the following section.

Results

Internal Capture

For internal capture of trips, coefficients and their significance levels (p-values) are shown in Table 6. The coefficients are elasticities of the odds of internal capture with respect to the various independent variables, that is, measures of effect size. In the case of home-based work trips, the odds of an internal trip decline with household size and vehicle ownership per capita, and increase with an MXD's job-population balance. Internal capture is thus related to two D variables, diversity and demographics. Larger households have more complex activity patterns that are more likely to take them beyond the bounds of an MXD. Households with higher vehicle ownership have fewer constraints on the use of household vehicles for long trips. A high job-population balance value translates into more opportunities to live and work on-site. The pseudo-R^2 of this model is quite low, at 0.01, indicating a considerable amount of unexplained influence on the odds of a home-based work trip being internally captured.

For home-based other trips, the odds of internal capture decline with household size and vehicle ownership per capita and increase with an MXD's land area, job-population balance, and intersection density. Internal capture for trips from home to nonwork destinations is thus related to development scale, diversity, design, and demographics. Relationships to household size and vehicle ownership are as explained previously. As for the other significant variables, job-population balance spawns on-site travel because jobs include those in the retail sector, suggesting the presence of shops and restaurants encourages some residents to substitute walk trips for out-of-neighborhood car trips. Also, a large land area increases the likelihood that nonwork destinations will be on-site while high intersection density increases routing options, makes routes more direct, creates frequent street crossing opportunities, and makes trips seem more eventful. Among the built environment variables analyzed, the most statistically significant predictor of internal capture for home-based other trips is job-population balance followed by an MXD's land area and then by its intersection density. The pseudo-R^2 of this model is a more respectable 0.20, but still indicates that there is a considerable amount of unexplained influence on the odds of a trip being internally captured

For non-home-based trips, the odds of internal capture decline with household size and vehicle ownership, and increase with land area, employment, and intersection density of the MXD. Internal capture is thus related to design, development scale, and demographics. Relationships to land area and intersection density were explained previously. The relationship to employment is likely attributable to the greater likelihood of matching employees'

Table 6. Log Odds of Internal Capture (Log-Log Form)

	Home-based work			Home-based other			Non-home-based		
	Coefficient	t-ratio	p-value	Coefficient	t-ratio	p-value	Coefficient	t-ratio	p-value
Constant	−1.75			−2.43			−5.32		
EMP	—	—	—	—	—	—	0.208	3.28	0.002
AREA	—	—	—	0.486	3.61	0.001	0.468	4.58	< 0.001
JOBPOP	0.389	2.62	0.010	0.399	4.55	< 0.001	—	—	—
INTDEN	—	—	—	0.385	1.92	0.055	0.638	4.95	< 0.001
HHSIZE	−1.33	−6.03	< 0.001	−0.867	−13.0	< 0.001	−0.237	−4.54	< 0.001
VEHCAP	−0.990	−4.15	< 0.001	−0.590	−8.19	< 0.001	−0.163	−3.00	0.003
Pseudo-R^2		0.01			0.20			0.30	

desired trips to on-site destinations when there are more attractions nearby. The most statistically significant relationship is to intersection density, followed by land area, and then by employment. The pseudo-R^2 of this model is highest of the three trip purposes, 0.30.

Although there is significant variance of internal capture from region to region, it is not explained by the variables in our data set. None of the Level 3 variables proved significant. This is not too surprising, given the small sample (six) of Level 3 units. Nonetheless, regional variance is captured in the random effects term of the Level 3 equation, just not explained by any of the regional variables.

Mode Choice for External Trips

Table 7 shows the coefficients and significance levels (p-values) of estimated models for predicting walk mode choice on external trips. The coefficients are elasticities of the odds of walking with respect to the various independent variables, that is, measures of effect size. For external home-based work trips, the odds of walking decline with household size and vehicle ownership per capita, and increase with job-population balance within the MXD and number of jobs outside the MXD within a mile of the boundaries. Walking on external trips is thus related to three types of D variables: diversity, destination accessibility, and demographics. Large households achieve economies through car pooling and trip chaining, and thus are less likely to walk. Households with more cars have a lower generalized cost of auto use, making them less likely to walk. Reasons for the positive association between internal job-population balance and walking for external work trips are less obvious. One possibility is that on-site balance creates opportunities for trip chaining. Another possibility is that on-site balance is associated with off-site, nearby balance as well, thus further inducing walk commutes. This is buttressed by the fact that the coefficient of EMPMILE is positive, indicating that when off-site job opportunities are nearby, MXD residents will walk to work. The pseudo-R^2 of this model is 0.19.

For external home-based other trips, the odds of walking decline with household size and vehicle ownership per capita, decline with the land area of the MXD, and increase with the activity density of the MXD, the job-population balance within the MXD, and number of jobs outside the MXD within a mile of the boundaries. Walking on external trips is thus related to measures of development scale, density, diversity, destination accessibility, and demographics. The larger the area of the MXD, the longer the external trips and the less likely they will be made by walking. The higher the activity density, the better the pedestrian environment and the more accessible attractions will be to those traveling into the community. Relationships to job-population balance and employment within a mile have already been discussed. The pseudo-R^2 of this model is a high 0.51.

For external non-home-based trips, the odds of walking decline with household size and vehicle ownership per capita, and increase with the activity density of the MXD, the intersection density of the MXD, and the number of jobs outside the MXD within a mile of the boundaries. Walking on external trips is thus related to measures of density, design, destination accessibility, and demographics. High intersection density within the MXD makes walking to/from activities outside the MXD that much more direct. The other independent variables have already been discussed. The pseudo-R^2 of this model is a very high 0.64. Overall, the external walk models have the greatest explanatory power of all models estimated.

Table 8 shows the coefficients and significance levels (p-values) of estimated models for predicting transit mode choice on external trips. For external home-based work trips, the odds of transit use decline with household size and vehicle ownership per capita, and

Table 7. Log Odds of Walking on External Trips (Log-Log Form)

	Home-based work			Home-based other			Non-home-based		
	Coefficient	t-ratio	p-value	Coefficient	t-ratio	p-value	Coefficient	t-ratio	p-value
Constant	−5.55			−10.96			−15.09		
AREA				−0.415	−4.27	< 0.001			
ACTDEN				0.370	2.74	0.007	0.377	3.12	0.003
JOBPOP	0.226	2.46	0.015	0.219	3.83	< 0.001			
INTDEN							0.803	5.05	< 0.001
EMPMILE	0.385	3.12	0.002	0.450	5.05	< 0.001	0.440	5.09	< 0.001
HHSIZE	−1.57	−6.29	< 0.001	−0.486	−5.05	< 0.001	−0.281	−2.59	0.010
VEHCAP	−1.84	−7.00	< 0.001	−0.768	−7.62	< 0.001	−0.242	−2.13	0.033
Pseudo-R^2		0.19			0.51			0.64	

Table 8. Log Odds of Using Transit on External Trips (Log-Log Form)

	Home-based work			Home-based other			Non-home-based		
	Coefficient	t-ratio	p-value	Coefficient	t-ratio	p-value	Coefficient	t-ratio	p-value
Constant	−8.05			−6.08			−2.69		
ACTDEN				0.324	2.89	0.005			
INTDEN	1.12	4.44	< 0.001						
EMP30T	0.209	2.98	0.004				0.134	3.29	0.002
HHSIZE	−1.14	−6.31	< 0.001	−0.958	−8.48	< 0.001			
VEHCAP	−1.68	−8.56	< 0.001	−1.09	−8.91	< 0.001	−0.340	−3.74	< 0.001
BUSSTOP	0.357	2.08	0.037	0.467	4.04	< 0.001			
Pseudo-R^2		0.47			NA			NA	

increase with the intersection density of the MXD and the number of jobs within a 30-min trip by transit. The odds of transit use are significantly higher for households living within 1/4 mile of a bus stop than those farther away. Transit use on external trips is thus related to measures of design, destination accessibility, distance to transit, and demographics. A higher intersection density translates into a more direct walk trips to and from transit stops, and also possibly more efficient routing of transit vehicles. More jobs within 30 min by transit increase the likelihood a particular job being within easy commuting distance for residents. Residence within the standard quarter mile walking distance of a bus stop shortens access trips. The pseudo-R^2 of this model is 0.48.

For external home-based other trips, the odds of transit use decline with household size and vehicle ownership per capita and increase with the activity density within the MXD. The odds are significantly higher for households living within 1/4 mile of a bus stop than those further away. The higher the activity density, the better the pedestrian environment and the more accessible attractions will be to those traveling into the community. The other independent variables have already been discussed. This is a weak model. The pseudo-R^2 of this model is a negative number because the combined variance at Levels 1 through 3 is greater for the estimated model than the null model with only an intercept and no explanatory variables.

For external non-home-based trips, the odds of transit use decline with household size and vehicle ownership per capita, and increase with the number of jobs within a 30 min trip by transit. These independent variables have already been discussed. The pseudo-R^2 of this model also is a negative number.

Regarding these negative pseudo-R^2s, a pseudo-R^2 is not entirely analogous to R^2 in linear regression, which can only assume positive values. One standard text on multilevel modeling notes that the variance can increase when variables are added to the null model. It goes on to say: "This is counterintuitive, because we have learned to expect that adding a variable will decrease the error variance, or at least keep it at its current level… In general, we suggest not setting too much store by the calculation of [pseudo-R2s]" (Kreft and de Leeuw 1998). For more discussion of negative pseudo-R^2s, also see Snijders and Bosker (1999).

Activity density has the expected positive sign in all three regressions. It reaches statistical significance in only one regression. This is consistent with a finding from a recent meta-analysis of the built environment-travel literature that density is the least important of the D variables (Ewing and Cervero 2010). Having a rail stop within a development also has a positive sign in all three regressions but never reaches statistical significance.

Although there is significant variance of walking and transit use from region to region, it is not explained by the variables in our data set. Again, none of the Level 3 variables proved significant. Regional variance is, however, captured in the random effects term of the Level 3 equation.

Trip Distance for External Automobile Trips

Table 9 shows the coefficients and significance levels (p-values) of estimated models for predicting auto trip distances on external trips. For external home-based work trips by private vehicle, trip distance increases with household size, vehicle ownership per capita, and land area of the MXD, and declines with a project's job-population balance and the share of regional jobs reachable within 30 min by automobile. External trip length is thus related to four types of D variables, development scale, diversity, destination accessibility, and demographics. Larger MXDs produce and attract longer external trips simply because the shortest trips are internalized. MXDs with good job-population balance apparently reduce the need for very long external trips; e.g., on-site residents patronizing on-site retail outlets. They may also facilitate trip chaining. MXDs with good auto accessibility to regional jobs generate shorter trips because more trip attractions are nearby. On the other hand, larger households have more complex activity patterns, which lengthen trips. More vehicles per household frees up family cars for trips to more distant destinations. These relationships match expectations. The pseudo-R^2 is 0.11.

For external home-based other trips, trip distance increases with household size and vehicle ownership per capita, and declines with the job-population balance within the MXD and the share of regional jobs reachable within 20 min by automobile. External trip length is thus related to measures of diversity, destination accessibility, and demographics. Relationships to job-population balance, accessibility to regional employment, household size, and vehicle ownership follow the same explanations provided above. The destination accessibility measure with the greatest explanatory power is the number of jobs reachable within 20 min by automobile, not 30 min as with home-based work trips. This makes sense, because home-based other trips are shorter than home-based work trips. The pseudo-R^2 of this model is 0.03.

For external non-home-based trips, trip distance increases with household size and vehicle ownership per capita, and declines with the job-population balance within the MXD, intersection density within the MXD, and the share of regional jobs reachable within 20 min by automobile. External trip length is thus related to measures of diversity, design, destination accessibility, and demographics. As for the one new variable, higher intersection density within an MXD (and perhaps its surroundings as well) makes for

Table 9. Trip Distance for External Automobile Trips (Semilog Form)

	Home-based work			Home-based other			Non-home-based		
	Coefficient	t-ratio	p-value	Coefficient	t-ratio	p-value	Coefficient	t-ratio	p-value
Constant	6.54			4.33			8.99		
AREA	1.07	2.92	0.004						
JOBPOP	−0.298	−1.88	0.061	−0.356	−2.38	0.018	−0.282	−2.05	0.041
INTDEN							−0.832	−2.06	0.041
EMP20A				−0.697	−4.79	< 0.001	−0.823	−5.69	< 0.001
EMP30A	−1.19	−6.05	< 0.001						
HHSIZE	2.76	8.08	< 0.001	0.772	5.06	< 0.001	0.520	2.58	0.010
VEHCAP	2.76	7.26	< 0.001	1.48	9.22	< 0.001	1.06	5.12	< 0.001
Pseudo-R^2		0.11			0.03			0.05	

more direct connections to external trip attractions. The pseudo-R^2 of this model is 0.05.

The VMT calculations made possible with the models presented in Tables 6–9 represent only the mileage generated by travel external to the development site. For large MXDs where internal vehicle travel is likely, users of the MXD method are advised to perform an independent estimate of internal vehicle trip generation and VMT. In these cases, internal and external VMT should be combined for complete estimates of impacts such as fuel consumption, greenhouse gases, and other emissions.

Model Validation

For this method to gain credibility, it is important that the results be validated by comparing estimates to in-field traffic counts. The preceding models were applied to 22 MXDs for which traffic counts of external vehicle trips were available. Six of those 22 sites are located in South Florida. Their traffic counts are presented in Appendix C of the *Trip Generation Handbook* (2004). Four additional sites are located in Central Florida, Atlanta, and Texas, of which three are nationally known examples of smart growth or transit-oriented development: Celebration Florida, Atlantic Station, and Mockingbird Station. Six sites are located in San Diego County and were designated by local planners and traffic engineers in 2009 as representing a wide range of examples of smart growth trip generators. The six remaining sites are conventional development projects located elsewhere in California. The sites represent a wide range of densities, land-use mixes, and development scales. Populations of the validation MXDs range from zero (Crocker Center in Boca Raton, FL and Hazard Center in San Diego, containing a mix of commercial and office uses only) to nearly 17,000 (the entire town of Moraga, CA). Employment levels range from near-zero (The Villages in Irvine, CA, which is predominantly residential, with only a small amount of restaurant and service retail) to more than 5,500 (Park Place, also in Irvine, CA). Some sites are well served by transit, including three built around rail stations, whereas others are suburban and poorly served by transit. With such a diverse validation sample, one can begin to build confidence that these MXD models have external validity.

Data were collected for all model variables at each of the 22 sites. The variables EMPMILE and EMP30T were estimated from regional travel models for the MXD traffic analysis zones and visually verified from aerials, and in some cases, from websites of the MXDs. For those sites for which household data were not available, the household size and vehicle ownership variables for trips produced and attracted to the MXD were taken from 2000 census data for the census tracts most closely matching the locations of the MXDs.

The probabilities estimated with these models and the resulting predicted external vehicle traffic counts are shown in Table 10. The results demonstrate that the models are capable of predicting a wide range of internal capture rates and mode shares for external trips, taking into account development scale, site design, and regional context. The models predict total vehicle counts within 20% of the actual number of trips observed for 15 of the 22 validation sites, within 30% for four sites, and within 40% for another one. Only two sites were off by more than 40%. When compared with the best available published methods for estimating trip generation, the models improved the prediction of vehicle counts at 16 of the 22 validation sites.

Table 11 compares model performance to current methods, specifically:

1. ITE *Trip Generation* or *SANDAG Traffic Generators* (2004) without any adjustments (Gross trips); and
2. Current internalization methods from the ITE *Trip Generation Handbook* or from SANDAG's current method of deducting 5% for mixed-use and 10% for proximity to transit (Net trips)

Table 10. Predicted Probabilities from Application of the Model to Validation Sites

Site name and location	Internal capture rate	External walk mode share	External transit mode share	Predicted external vehicle counts	Observed external vehicle counts
Atlantic Station, Atlanta, GA	11%	7%	4%	31,377	28,787
Boca Del Mar, Boca Raton, FL	10%	3%	2%	20,890	22,846
Town of Celebration, Celebration, FL	26%	2%	0%	35,775	40,912
Country Isles, Weston, FL	9%	0%	0%	14,891	22,419
Crocker Center, Boca Raton, FL	3%	4%	3%	17,077	9,791
Galleria, Ft. Lauderdale, FL	9%	3%	3%	29,505	22,971
Gateway Oaks, Sacramento, CA	11%	4%	3%	16,320	23,280
Jamboree Center, Irvine, CA	9%	5%	4%	36,039	36,569
Legacy Town Center, Plano, TX	14%	12%	4%	24,903	20,082
Mizner Park, Boca Raton, FL	8%	9%	5%	11,559	12,086
Mockingbird Station, Dallas, TX	6%	19%	6%	11,153	20,677
Town of Moraga, Moraga, CA	28%	1%	1%	55,816	49,689
Park Place, Irvine, CA	7%	7%	4%	17,417	19,064
South Davis, Davis, CA	25%	2%	2%	66,752	74,648
The Villages, Irvine, CA	2%	7%	4%	7,680	7,128
Village Commons, West Palm Beach, FL	6%	4%	0%	22,793	18,075
Rio Vista, San Diego, CA	4%	15%	7%	5,024	5,307
Village Plaza, La Mesa, CA	7%	17%	8%	3,920	4,280
Uptown Center, San Diego, CA	6%	17%	6%	14,734	16,886
Morena Linda Vista, San Diego, CA	6%	16%	7%	4,132	4,712
Hazard Center, San Diego, CA	5%	10%	8%	11,685	11,644
Otay Ranch, Chula Vista, CA	5%	3%	4%	9,279	7,935

Table 11. Comparison of Percent Differences between Predicted and Observed External Vehicle Counts by Gross, Net, and MXD Modeling Methods

Site name and location	Gross trips[a]	Net trips[b]	MXD method
Atlantic Station, Atlanta, GA	37%	25%	9%
Boca Del Mar, Boca Raton, FL	7%	−4%	−9%
Town of Celebration, Celebration, FL	21%	17%	−13%
Country Isles, Weston, FL	−27%	−38%	−34%
Crocker Center, Boca Raton, FL	94%	82%	74%
Galleria, Ft. Lauderdale, FL	50%	35%	28%
Gateway Oaks, Sacramento, CA	−15%	−19%	−30%
Jamboree Center, Irvine, CA	20%	8%	−1%
Legacy Town Center, Plano, TX	74%	50%	24%
Mizner Park, Boca Raton, FL	20%	20%	−4%
Mockingbird Station, Dallas, TX	−24%	−26%	−46%
Town of Moraga, Moraga, CA	59%	49%	12%
Park Place, Irvine, CA	10%	4%	−9%
South Davis, Davis, CA	24%	3%	−11%
The Villages, Irvine, CA	22%	17%	8%
Village Commons, West Palm Beach, FL	40%	31%	26%
Rio Vista, San Diego, CA	26%	8%	−5%
Village Plaza, La Mesa, CA	33%	13%	−8%
Uptown Center, San Diego, CA	20%	8%	−13%
Morena Linda Vista, San Diego, CA	35%	16%	−12%
Hazard Center, San Diego, CA	29%	11%	0%
Otay Ranch, Chula Vista, CA	32%	19%	17%
RMSE	44%	32%	22%
R^2	0.65	0.81	0.92

[a]Gross trips estimates are computed from the trip generation rates contained in the ITE *Trip Generation* report (sites 1–16) or the *SANDAG Traffic Generators* report (sites 17–22) for each of the individual land uses within the mixed-use site, without discounting for internalization, walking or transit use.
[b]Net trips estimates apply internalization reductions for multiuse sites as prescribed in the ITE *Trip Generation Handbook* (sites 1–16) or the *SANDAG Traffic Generators* report (sites 17–22) and represent the best estimates that one could obtain relying on currently published material alone.

Percentages reported in Table 11 indicate errors in trip estimates using gross, net, and MXD modeling methods, respectively, for each testing site. The percent root mean squared error (%RMSE), used in the transportation field to evaluate model accuracy, penalizes proportionally more for large errors and normalizes the error across different values of the quantity one is trying predict. A % RMSE of less than 40% is generally considered good. Table 11 shows that the proposed models improve the %RMSE over the gross and net methods. The MXD models improve the %RMSE from 32%, produced by the best of the previously available trip generation estimation methods, to a figure of 22%.

R^2 in this table measures the squared difference between the observed and predicted external vehicle counts as a percentage of the squared variation of the observed external vehicle counts about the mean over the 22 sites. Table 11 shows that the proposed models also improve the R^2 significantly compared to the gross and net methods. The R^2 for the MXD model is 0.92, markedly better than the 0.81 value for the net method, the best estimates that one could obtain relying on previously published material alone.

Finally, Figs. 4 and 5 show the strong association between predicted and observed external vehicle counts using the models developed herein, and a comparison of daily observed external vehicle counts across the three methods.

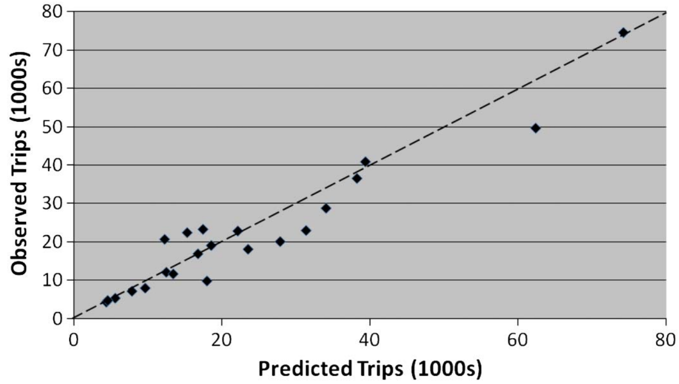

Fig. 4. Scatterplot of predicted versus observed external vehicle counts

Applications

The previously derived models can be used to predict trip productions plus attractions for three separate trip purposes. Having the models for three trip purposes allows the practitioner to predict external private vehicle trips on either a daily basis or a morning or afternoon peak hour basis. The likelihood that a trip during any of these times of day is home-based-work or home-based-other or non-home-based is determined based on purpose-specific trip generation rates in NCHRP Report 365, *Travel Estimation Techniques for Urban Planning* (1998). The log odds estimates of internal capture or walk or transit, as obtained from Tables 6–8, are first exponentiated, then converted into probabilities using the formula: probability $=$ odds$/(1+$odds$)$. They are then applied to each estimate of total trips generated for the three trip purposes. The remaining trips are combined across all three trip purposes to get total net external private vehicle trips.

The models are applied in sequential fashion for each trip purpose. The probability of trips for a given trip purpose traveling external to the site is computed first, using the equations in Table 6. These resulting probabilities are used to discount the total site trip generation as estimated by the trip rates contained in the ITE *Trip Generation* report. The resulting external trips are then further reduced to account for those external trips that would probabilistically travel by walking or transit, using the equations provided in Tables 7 and 8. The three trip purposes are then combined. This leaves the estimate of external vehicle trips, or in ITE terms, site traffic generation. For those who want to compute the VMT generated by the site, one would apply the Table 9 equations to compute the average external trip lengths, and for large sites, would add an estimate of VMT generated by trips remaining entirely within the site.

Most of the information required to apply these equations is readily available from project site plans and programmatic data developed as part of a project planning process or submitted as part of a development application. Certain data items may require the traffic engineer to obtain information via GIS mapping of the site area or a request to the jurisdiction or metropolitan planning organization for information easily extracted from the regional travel model. These data, when incorporated into equations that estimate MXD internal capture and walking and transit use, produce trip generation reductions to be applied to estimates based on the ITE *Trip Generation* report.

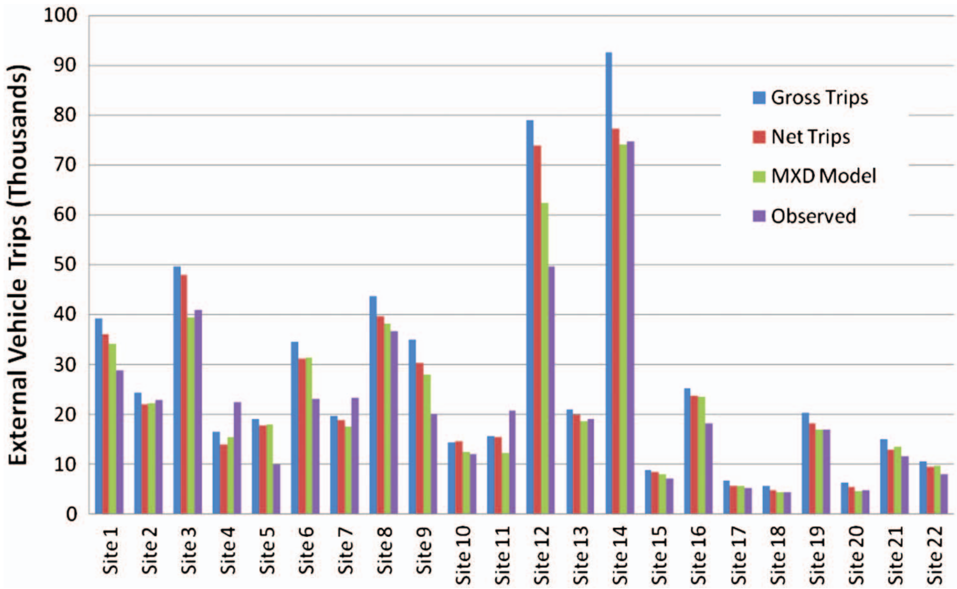

Fig. 5. (Color) Comparison of external vehicle trips across methods

As is the case with many of the guidelines presented in *Trip Generation*, expert judgment is advised on case-by-case basis. This might be necessary if, for example, in the judgment of a qualified traffic engineer or planner, the development proposal under study is unique in its relative composition of restaurant, theater, or other commercial uses.

Conclusion

The bibles of traffic impact analysis, the Institute of Transportation Engineers' *Trip Generation* report (2008) and *Trip Generation Handbook* (2004), are sorely lacking when it comes to MXDs. Except for a handful of master-planned projects in Florida, actual studies of internal capture rates are few and far between. Traffic engineers are thus largely left to their own devices when quantifying the trip reductions that might result from mixing land uses. Therefore, to err on the conservative side and avoid possible liability charges from underdesigning road capacity, often no adjustment is made at all. This results in overestimates of the traffic impacts of MXD proposals, leading to higher development fees than necessary and raising opposition among those who fear potential adverse impacts. Failure to account for internal capture and external walk and transit trips ends up penalizing MXDs and can force MXD developers to, in effect, cross-subsidize single-use projects through disproportionate exactions. In addition, lack of accounting for the trip-reducing benefits of MXDs can result in an oversupply of parking.

This research sought to advance the state of knowledge on the relationships that govern travel to, from, and within mixed-use development projects and to enumerate tangible and verifiable traffic reductions relative to the rates in the ITE *Trip Generation* report. Travel research published over the last few years convincingly shows that changes by several percentage points in any or several of the D variables used in this study reduces the number of vehicle trips and vehicle miles traveled (Ewing and Cervero 2001, 2010). This study extends and focuses that research on the particular characteristics of MXDs. It represents the first national study of the traffic generation by mixed-use developments, making use of household travel survey data from six metropolitan regions. The writers found that an average of three out of 10 trips generated by MXDs put no strain on the external street network and generate relatively few vehicle miles traveled. Statistical equations derived from the data reveal that the primary factors affecting this reduction in automobile travel are:

1. The total and the relative amounts of population and employment on the site;
2. The site size and activity density;
3. The size of households and their auto ownership;
4. The amount of employment within walking distance of the site;
5. The block size on the site; and
6. The access to employment within a 30 min transit ride of the site.

For traffic impact, greenhouse gas, and energy analyses, the VMT generated by a mixed-use site depends, in addition to the previously described factors, on the site's placement within the region, specifically, on the share of jobs located within a 20- to 30-min drive of the site. Greater destination accessibility translates into shorter auto trips external to the site. This effect is as significant as the effects associated with internal capture of trips within mixed-use developments, and conversion of some external trips from auto to alternate modes.

This study's findings regarding the factors that influence mixed-use trip generation have been validated through field surveys at illustrative sites in California, Florida, Georgia, and Texas. The results will help guide planners and developers of mixed-use projects on design features likely to minimize traffic generation, greenhouse gas emissions, and energy impacts, and will produce new analysis techniques for traffic engineers to more realistically quantify infrastructure impacts of mixed-use development proposals.

There are five caveats for practitioners. First, although MXDs offer the option of walking, not all internally captured trips are walk trips. This study focuses on MXD effects on external trip generation. Microscale built environmental features and their influence on short-distance driving and nonmotorized trip-making in MXDs warrant further investigation.

Second, when applying these models, internal capture rates computed with the formulas are presumptive rates. They still need to be adjusted to balance productions and attractions within the site, as with the ITE *Trip Generation Handbook* method.

Third, owing to limitations of the hierarchical modeling software the writers used (HLM), we specified two binomial mode choice models (walk or not, transit or not) rather than one multinomial mode choice model (walk, transit, or auto). As a suggestion for future research, it might be possible to estimate a multinomial model with different software. As it is, the "not" alternative in each case ("not walking," "not transit") is quite heterogeneous, including all other alternatives. It would be more behaviorally sound (and therefore may well increase the goodness-of-fit of the models) to explicitly divide the "not" alternative into its constituent modes: a traveler probably does not usually say, "should I take transit or not?" but rather, "should I drive, walk, or take transit?"

Fourth, while acknowledging that walk trips may supplement rather than substitute for private vehicle trips, we have in our validation exercise treated walking and transit use as one-for-one, trip-for-trip substitutes for private vehicle trips. Our data set prevents us from estimating trip generation rates by mode because we have only a sample of trips to, from, and within MXDs to work with, not the full set of trip ends for nonresidential trip generators. This, in turn, forces us to estimate mode choice equations, and keeps us from drawing any inference about trip substitution. Because some of the walk trips may supplement automobile trips, our walk mode choice models represent an upper bound on actual rates of substitution.

Finally, the MXD methods presented here do not explicitly account for the effects of parking supply and price. Although several of the variables included in the analysis, such as development density and proximity to regional job centers, may be partial proxies for parking supply and price, site-specific parking data were not available and were, therefore, not included in the MXD models. If parking supply and price data were available they might significantly improve the ability to predict trip generation. It would also inform the discussion of how MXDs can reduce trip generation by pricing, supply constraint and unbundling the cost of parking from the cost of real estate.

In closing, smart growth requires smart calculations. Unless developers are rewarded for the trip-reducing impacts of MXDs, the market incentive to build projects with relatively small environmental footprints is substantially reduced. Although the technical aspects of this work might not be accessible to city planning commissioners and lay citizens, the basic premise that good development should be rewarded can be understood by all.

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