California Smart-Growth Trip Generation Rates Study

Final Report

Appendix F

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METHODOLOGY FOR ADJUSTING ITE TRIP GENERATION ESTIMATES FOR SMART-GROWTH PROJECTS

California Smart-Growth Trip Generation Rates Study

University of California, Davis for the California Department of Transportation
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Methodology for Adjusting ITE Trip Generation Estimates for Smart-Growth Projects

This methodology can be used by practitioners to adjust estimates based on existing ITE rates and equations to produce more accurate weekday AM and PM peak hour vehicle trip generation rate estimates at developments with particular smart-growth characteristics. It takes estimates of vehicle trips based on ITE trip generation rates and adjusts them based on characteristics of the proposed development project and its surrounding context. At the core of the methodology are simple linear regression equations with the AM or PM adjustment factor as the dependent variable and easily-measured site and context characteristics as the explanatory variables. These AM and PM equations were developed using a database of vehicle trip counts and site/context data for a sample of 50 "smart-growth" sites in California.

The resulting models are only appropriate for planning-level analysis at single-use sites or single land uses that are a part of multi-use sites. The models are only appropriate for certain land use categories, and they do not apply to multi-use developments as a whole. Existing ITE methods should be used instead of these models to assess trip generation (including internal capture trips) at multi-use developments. They are also appropriate only for sites in smart-growth areas. Specific criteria that should be met in order to apply the models are described in more detail, below.

1. Background

Prior analysis showed that motor vehicle trips generated by a sample of smart-growth study sites[1] in California were, on average, approximately half as high as predicted by standard ITE trip generation rates. One of the primary reasons for this difference is that pedestrian, public transit, and bicycle modes are used instead of motor vehicles for a portion of trips in smart-growth areas. However, the difference between actual vehicle trips and ITE-estimated vehicle trips varied from site to site. In order to provide the best possible estimates of vehicle trips at new development sites in smart-growth areas, it is necessary to account for this variation. This memorandum presents models that can be used to adjust ITE vehicle trip generation estimates based on specific smart-growth site characteristics. One model is has been developed for the morning (AM) peak hour, and another model has been developed for the afternoon (PM) peak hour. ***Unlike other ITE adjustment approaches, these models are only appropriate for sites in smart-growth areas.***

The starting point for the model development process is the extensive literature on the connections between characteristics of the built environment and travel behavior. Empirical evidence points to the importance of factors such as population density and land use mix as predictors of trip frequency and mode choice. Guided by this evidence, we created a database

[1] Most data for this study were collected from individual land uses. Some of these individual land uses were the only use on a property; others were part of a multi-use development but were isolated for data collection. Some data were also collected on the boundary of properties with more than one land use (i.e., multi-use developments). Collectively, the single land uses and multi-use developments analyzed in the study are referred to as "study sites" in this document.

of potential explanatory factors—variables that may predict the difference between actual trip generation at smart-growth development projects and trips rates as estimated based on ITE-rates. In order to create theoretically-sound models that are also practical to use, we tested many variables that would be relatively easy to measure or acquire.

2. Data Used for Modeling and Validation

The adjustment methodology was based on trip generation data from more than 50 study sites in smart-growth areas. The sites used for model development and model validation are listed in Appendix A. Trip generation data at the study sites were gathered from several different sources, including field data collection by the UC Davis research team in Spring 2012. The data collection sources and methodologies are summarized in Table 1.

Table 1. Sources of Trip Generation Data at Study Locations

Source	# of Study Sites	Data Collection Timeframe	Data Collection Approach	Source for more Detailed Information
EPA MXD Study: "Trip Generation Tool for Mixed-Use Developments"	3	Fall 2007	Pneumatic tube counts	http://www.epa.gov/smartgrowth/ mxd_tripgeneration.html
TCRP Report 128: "Effects of TOD on Housing, Parking, and Travel"	5	Spring 2007	Pneumatic tube counts	http://onlinepubs.trb.org/onlinepubs/ tcrp/tcrp_rpt_128.pdf
Caltrans Infill Study: "Trip-Generation Rates for Urban Infill Land Uses in California Phase 2: Data Collection FINAL REPORT"	22	Spring 2006 Spring 2007 Fall 2007 Spring 2008 Fall 2008	Door counts and intercept surveys	http://www.dot.ca.gov/research/ researchreports/reports/2009/ final_summary_report-calif._infill_trip-generation_rates_study_july_2009.pdf
San Diego Association of Governments (SANDAG) MXD Study: "Trip Generation for Smart Growth: Planning Tools for the San Diego Region"	6	Fall 2008 Spring 2009	Pneumatic tube counts	http://www.sandag.org/ tripgeneration
Fehr & Peers data collection at multi- or mixed-use sites	2	Fall 2010	Pneumatic tube counts	
UC Davis field data collection	30	Spring 2012	Door counts and intercept surveys	Project data collection and results report

2.1. Sites Used for Model Development

Overall, 46 sites were used for AM model development and 50 sites were used for PM model development. These sites represented common land use categories, including mid- to high-density residential, office, coffee/donut shop, and general retail (Table 2).

Table 2. Model Land Use Category

General Land Use Category	AM Model	PM Model
Mid-to High-Density Residential	20	20
Office	11	12
Coffee/Donut	3	3
Multi-Use Development	11	11
Retail	0	3
Other (Restaurant)	1	1
Total Sites	**46**	**50**

2.2. Sites Used for Model Validation

Some of the study sites were located close to another study site, and some of the targeted land uses with trip generation data were actually in the same development. The land uses in the same development also shared nearly all of the same context characteristics, and including them together in the model would violate the statistical assumption that the data in the model are independent. To avoid this problem, sites within one-quarter mile of other sites and the second or third targeted land use in the same development were set aside for validation. This process produced 11 sites for AM model validation and 13 sites for PM model validation.

2.3. Sites Excluded from the Analysis

Several potential sites were excluded from the analysis for the following reasons:

- No field data were collected or reported at the site.
- Fewer than 10 trips were reported during the peak hour.
- Trip mode split was based on fewer than 30 surveys at a Spring 2012 data collection site.
- Site had trips at non-standard hours for a particular land use (e.g., clothing store with many trips during the AM period).
- Retail site had an abnormally-high customer base (e.g., the only grocery store serving an entire downtown area).

2.4. Recommended Site Criteria for Model Application

Because the models are based on study sites with specific on-site and surrounding neighborhood characteristics, they should be applied in locations that have similar characteristics. Therefore, the specific criteria listed below have been established to identify sites where it is appropriate to use the models. Further, to ensure that the locations where the models are applied truly represent smart-growth, the minimum population density, employment density, and transit service criteria are slightly more stringent (i.e., more representative of smart-growth) than the minimum values of these variables from the sites used for model development.

1. The AM and PM models were developed using data from study sites in several common general land use categories, including mid- to high-density residential (ITE Trip Generation Manual Land Use Codes 220, 222, 223, 230, 232), office (710), restaurant (925, 931), and

coffee/donut shop (936)[2]. Therefore, it is appropriate to apply the models to sites in these land use categories. The PM model was also developed using several retail land uses (820, 867,880) so it could be appropriate for these classifications. It could also be appropriate for other retail uses (e.g., 813, 814, 815) that are likely to experience vehicle trip reductions similar to the reductions experienced by residential, office, restaurant, and coffee/donut shop uses when they are located in smart-growth areas. However, the PM model should be applied with caution to retail land uses (e.g., a retail store that specializes in large goods may generate automobile trip numbers similar to ITE predictions even if it is in a smart-growth area). Note that the AM model does not apply to retail uses. The AM and PM models should not be used for any other land uses than those listed above.

2. It is recommended that the models be applied only at sites that meet all four of the following smart-growth development criteria:

1) The area within a 0.5-mile radius of the site is mostly (>80%) developed (rural land and open space are "undeveloped")[3].
2) There is a mix of land uses within a 0.25-mile radius of the site (i.e., there are at least two different major land use categories, such as residential, office, retail, industrial, etc.)[4].
3) J>4,000 and R>(6,900-0.1J), where J is the number of jobs within a 0.5-mile radius of the site and R is the number of residents within a 0.5-mile radius of the site[5].
4) There are no special attractors within a 0.25-mile radius of the site (e.g., stadiums, military bases, commercial airports, major tourist attractions)[6].

3. It is recommended that the models be applied only at sites that meet the following smart-growth transit service criterion:

1) During a typical weekday PM peak hour, there are at least:
    a) 10 bus stop locations on all bus lines that pass within any part of a 0.25-mile radius around the study site, or
    b) 5 individual train stop locations on all train lines that pass within any part of a 0.5-mile radius around the study site during a typical weekday PM peak hour[7].

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[2] Specific land use codes are described in the ITE Trip Generation Manual, Ninth Edition.

[3] Land within a 0.5-mile, straight-line radius from the center of the site is considered developed if it is not rural land or open space.

[4] Land uses within a 0.25-mile, straight-line radius from the center of the site are distinguished for individual units (unique addresses) within each parcel.

[5] The 0.5-mile, straight-line radius is measured from the center of the site. This measure was calculated in GIS for model development using US Census block group data (2010), but it is also possible to estimate the population and jobs within 0.5-miles from online sources.

[6] Special attractors within a 0.25-mile, straight-line radius from the center of the site include stadiums, military bases, commercial airports, major tourist attractions, or other land uses that generate high volumes of traffic at specific times.

[7] Number of individual bus stop locations on all bus lines that pass within any part of a 0.25-mile radius around the study site during a typical weekday PM peak hour. For example, consider a site that has two bus stops, A and B within a straight-line 0.25-mile radius from the center of the site. During the weekday PM peak hour, bus stop A serves bus lines 17, 28, and 52. Meanwhile, bus stop B serves bus lines 21, 28, and 52. In this case, the total stop

4. It is recommended that the models be applied only at sites that meet at least one of the two following smart-growth pedestrian or bicycle criteria:

1) There is at least one designated bicycle facility within two blocks of the edge of the site (designated bicycle facilities include multi-use trails, cycle tracks, and bicycle lanes; they do not include shared lane markings or basic bicycle route signs with no other facilities)[8].
2) There is >50% sidewalk coverage on streets within a 0.25-mile radius of the site[9].

Note that all radii are measured as straight-line distances (rather than street network distances) from the center of the site (rather than the edge).

3. Dependent Variable

The difference between the number of actual vehicle trips and the number of vehicle trips estimated from standard ITE rates was calculated for morning (AM) and afternoon (PM) peak-hour periods at all of the study sites. The dependent variable used in the models was the natural log (ln) of the ratio of actual vehicle trips divided by ITE-estimated vehicle trips at each smart-growth study site:

ln(actual vehicle trips/ITE-estimated vehicle trips)

This variable is easy to interpret. Smart-growth sites that have fewer vehicle trips (i.e., a greater difference between actual and ITE-estimated trips) have a smaller ratio of actual to ITE-estimated trips. It is important to use a ratio rather than the difference between actual and ITE-estimated trips because the ratio controls for the size of sample sites. If the difference was used as the dependent variable, the largest absolute differences would be at the largest sites. The natural-log transformation was applied for statistical modeling purposes. Descriptive statistics for the dependent variables used in the AM and PM models are shown in Table 3 (the ratios of actual vehicle trips/ITE-estimated vehicle trips are included to provide an intuitive comparison to the natural-log-transformed versions of the variables).

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locations on all bus lines that pass within any part of a 0.25-mile radius around the study site during a typical weekday PM peak hour is 6 (bus line 17 has one stop location, bus line 21 has one stop location, bus line 28 has two stop locations, and bus line 52 has two stop locations). The frequency of bus service on each line is not considered. PM peak-hour train line stops are calculated using a similar method.

[8] Designated bicycle facilities include multi-use trails, cycle tracks, and bicycle lanes; they do not include shared lane markings or basic bicycle route signs with no other facilities. They are counted if they are within two blocks of the edge of the site.

[9] Sidewalk coverage considers both sides of the roadway. Sidewalks on both sides of a roadway segment is considered to be 100% coverage. A sidewalk on only one side is considered to be 50% coverage. Sidewalks on both sides of the roadway for only half of the length of the segment is considered to be 50% coverage.

Table 3. Dependent Variable Descriptive Statistics

Variable	N	Minimum	Maximum	Mean	Std. Dev.
Actual AM vehicle trips/ITE-estimated AM vehicle trips	46	0.112	3.289	0.650	0.513
ln(actual AM vehicle trips/ITE-estimated AM vehicle trips)	46	-2.187	1.190	-0.648	0.664
Actual PM vehicle trips/ITE-estimated PM vehicle trips	50	0.090	2.215	0.583	0.356
ln(actual PM vehicle trips/ITE-estimated PM vehicle trips)	50	-2.413	0.795	-0.705	0.603

4. Explanatory Variables

While the literature has identified many factors that link built environment characteristics to trip generation, only a subset of these factors are readily available or easy to measure. The modeling process focused on those variables that are readily available or relatively easy to measure within a predefined (e.g. 0.25-mile) radius around the site location. Several categories of site characteristics were hypothesized to be associated with the ratio of actual to ITE-estimated vehicle trips. These characteristics were measured for all sample sites and represented by the explanatory variables listed in Appendix B. Explanatory variable descriptive statistics are presented in Appendix C.

Once the database of explanatory variables was assembled, we examined the correlations between potential explanatory variables and the ratio of actual to ITE-estimated trips, as well as correlations among the variables. This process helped to identify which potential explanatory variables were the most promising to include in models (i.e., those variables with relatively high correlations with the trip ratio) and helped to identify related sets of explanatory variables.

5. Modeling Process

In order to account for correlation between many of the potential explanatory variables, a two-step approach was used to identify the statistical association between explanatory variables and the dependent variable during the AM peak hour and the PM peak hour.

Step 1: Use Factor Analysis to Create a Smart-Growth Factor

In developing these models, factor analysis (principal axis factoring to specify one factor) was first used to create a formula for a “smart-growth factor” (SGF). This factor is a linear combination of eight variables, each weighted according to its contribution to explaining the variation among the 50 PM study sites (Table 4). Variables included in the SGF represent distinguishing characteristics of smart-growth developments. Positive coefficients indicate that increasing the value of the variable produces a higher SGF value, which indicates that the site is more representative of smart-growth; negative coefficients indicate that increasing the value of the variable produces a lower SGF value, which indicates that the site is less representative of smart-growth. Several other variables were also considered as potential components of the SGF (e.g., number of four-way intersections near the site; number of lanes on roadways bounding the site; percentage of households with no vehicles within the census tract at the site). However, the iterative modeling process (described below) indicated that the eight-variable SGF had the greatest statistical association with the dependent variable, so it was used in the final models.

Note that the variables used in the SGF are available from common data sources (Table 5).

Table 4. Smart-Growth Factor

Variable	**Coefficient**[1]
Residential population within a 0.5-mile, straight-line radius (000s)[2]	0.099
Jobs within a 0.5-mile, straight-line radius (000s)[3]	0.324
Straight-line distance to center of central business district (CBD) (miles)[4]	-0.138
Average building setback distance from sidewalk (feet)[5]	-0.167
Metered on-street parking within a 0.1-mile, straight-line radius (1=yes, 0=no)[6]	0.184
Individual PM peak-hour bus line stops passing within a 0.25-mile, straight-line radius[7]	0.227
Individual PM peak-hour train line stops passing within a 0.5-mile, straight-line radius[8]	0.053
Proportion of site area covered by surface parking lots (0.00 to 1.00)[9]	-0.080

Notes:

1. This coefficient is applied to the standardized version of the variable. The standardized value is calculated using the mean and standard deviation of variable values from the 50 PM analysis sites.
2. The 0.5-mile, straight-line radius is measured from the center of the site. This measure was calculated in GIS for model development using US Census block group data (2010), but it is also possible to estimate the population within 0.5-miles from online sources.
3. The 0.5-mile, straight-line radius is measured from the center of the site. This measure was calculated in GIS for model development using US Census block group data (2010), but it is also possible to estimate the employment within 0.5-miles from online sources.
4. Straight-line distance from center of study site to center of the regional central business district (CBD). Example regional CBDs include Los Angeles, San Diego, San Francisco, Sacramento, and Oakland. Sub-regional centers such as Walnut Creek or Pasadena are not classified as CBDs.
5. Average building setback is the average straight-line distance to the sidewalk from all major building entrances (feet). Major entrances include the main pedestrian entrance and automobile garage entrances.
6. Metered parking only includes metered on-street parking. Metered off-street surface lots or parking structures are not included. The 0.1-mile, straight-line radius is measured from the center of the site.
7. Number of individual bus stop locations on all bus lines that pass within any part of a 0.25-mile radius around the study site during a typical weekday PM peak hour. For example, consider a site that has two bus stops, A and B within a straight-line 0.25-mile radius from the center of the site. During the weekday PM peak hour, bus stop A serves bus lines 17, 28, and 52. Meanwhile, bus stop B serves bus lines 21, 28, and 52. In this case, the total stop locations on all bus lines that pass within any part of a 0.25-mile radius around the study site during a typical weekday PM peak hour is 6 (bus line 17 has one stop location, bus line 21 has one stop location, bus line 28 has two stop locations, and bus line 52 has two stop locations). The frequency of bus service on each line is not considered. PM peak-hour train line stops are calculated using a similar method.
8. Number of individual train stop locations on all train lines that pass within any part of a 0.5-mile radius around the study site during a typical weekday PM peak hour. For an example, see the bus stop location description.
9. Proportion of site surface area covered by surface parking lots does not include surface area covered by parking structures. Therefore, sites that only have parking garages should be given a value of 0.00.

Table 5. Smart-Growth Factor Variables: Example Data Sources

Variable	Example Data Source
Residential population within a 0.5-mile, straight-line radius (000s)[1]	US Census: Missouri Census Data Center, mcdc.missouri.edu/websas/caps10c.html[2]
Jobs within a 0.5-mile, straight-line radius (000s)[1]	US Census Longitudinal Employer-Household Dynamics, http://onthemap.ces.census.gov/[2]
Straight-line distance to center of central business district (CBD) (miles)	Google Earth (http://www.google.com/earth/index.html)
Average building setback distance from sidewalk (feet)	Google Earth (http://www.google.com/earth/index.html)
Metered on-street parking within a 0.1-mile, straight-line radius (1=yes, 0=no)	Google Street View (https://maps.google.com/)
Individual PM peak-hour bus line stops passing within a 0.25-mile, straight-line radius	Local Transit Agency Bus Schedule (local transit agency website)
Individual PM peak-hour train line stops passing within a 0.5-mile, straight-line radius	Local Transit Agency Train Schedule (local transit agency website)
Proportion of site area covered by surface parking lots (0.00 to 1.00)	Google Earth (http://www.google.com/earth/index.html)

Notes:

1. The population and employment measures used to develop the model were calculated from raw population data, which are available from the US Census Factfinder website (http://factfinder2.census.gov), and raw employment data, which are available from the US Census Longitudinal Household-Employment Dynamics website (http://onthemap.ces.census.gov/). Most MPOs already have population and employment data converted into GIS shapefiles at the census block group level, so they are a good source of raw data. The following steps were done in GIS to calculate the population (or employment) within 0.5 miles of the center of each study site: 1) Create a point at the center of the site. 2) Create a 0.5-mile buffer around the site center point (this is a circle with a radius of 0.5 miles). 3) Calculate the area of all census block groups within several miles of the site (this was done for the entire state). 4) Use the ArcGIS "Intersect" tool to intersect the census block group layer with 0.5-mile buffer layer. This "cuts" any census block groups that straddle the buffer boundary into new shapes (these newly cut shapes are saved as a new shapefile that also contains the other existing census block groups that were not "cut"). 5) Re-calculate the area of all of the shapes in the new shapefile. Divide the new area by the old area to identify proportion of each census block group that is inside (and outside) the buffer boundary. 6) Multiply the total population (employment) within each census block group by the proportion of the census block group that is within the buffer boundary (e.g., if one-quarter of a census block group with 100 residents is within the buffer boundary, then 25 people are assumed to live within the buffer boundary and 75 people live outside the buffer boundary). Note that this assumes an even spatial distribution of the population (employment) within a census block group. 7) Sum the recalculated population (employment) of all census block groups and parts of census block groups that are within the 0.5-mile buffer.
2. There are also several online tools that can be used to approximate the total population and jobs within 0.5 miles of a study site: Population within a specified buffer distance (0.5 miles) around a specific point (latitude, longitude) can be calculated from the Missouri Census Data Center website (mcdc.missouri.edu/websas/caps10c.html). Employment within a specified buffer distance (0.5 miles) around a specific point (address) is available from the US Census Longitudinal Household-Employment Dynamics website (http://onthemap.ces.census.gov/). Depending on the preliminary data, it may be necessary to convert from address to latitude, longitude points. This can be done easily using Google Earth or websites like itouchmap.com/latlong.html or geocoder.us. Note of caution: the online websites (Missouri Census Data Center and Longitudinal Household-Employment Dynamics) estimate population within the buffer area using whole census blocks. They do not allocate the proportion of the census block that is within the buffer area. For census blocks that straddle the buffer line, they simply add the total population of the census block if more than half of the block is within the buffer line or add zero population if less than half of the block is within the buffer line. This creates less accurate estimates than were used for model development, especially in areas that have larger-area census blocks (i.e., more suburban areas). However, the estimated population and employment numbers should be sufficient for planning-level analysis.

Means and standard deviations of each SGF variable were calculated for the 50 PM study sites (Table 6). These values are necessary to calculate standardized versions of the variable when applying this method in practice.

Table 6. Smart-Growth Factor Variable Descriptive Statistics based on 50 PM Peak Hour Study Sites

Variable	N	Minimum	Maximum	Mean	Std. Dev.
Residential population within a 0.5-mile, straight-line radius (000s)	50	0.787	42.109	9.718	6.811
Jobs within a 0.5-mile, straight-line radius (000s)	50	0.487	136.400	24.351	29.899
Straight-line distance to center of central business district (CBD) (miles)	50	0.029	40.100	7.746	9.489
Average building setback distance from sidewalk (feet)	50	0.000	524.000	76.020	115.644
Metered on-street parking within a 0.1-mile, straight-line radius (1=yes, 0=no)	50	0.000	1.000	0.620	0.490
Individual PM peak-hour bus line stops passing within a 0.25-mile, straight-line radius	50	0.000	255.000	43.420	50.836
Individual PM peak-hour train line stops passing within a 0.5-mile, straight-line radius	50	0.000	59.000	6.820	12.141
Proportion of site area covered by surface parking lots (0.00 to 1.00)	50	0.000	0.500	0.063	0.124

<u>Step 2: Estimate Ordinary Least Squares Regression Models</u>

The SGF was considered as a potential explanatory variable in a series of ordinary least squares regression models. Several versions of the SGF and many combinations of the SGF along with other land use indicator (dummy) variables were tested through an iterative process of model fitting. Testing used both step-forward techniques (in which variables are entered into the model one at a time), and step-backward techniques (in which all variables are entered into the model at the outset, then eliminated one at a time based on which is least statistically significant). In evaluating the different models estimated, we considered a combination of the overall explanatory power of each model, the statistical significance of the coefficients for individual variables, and the theoretical importance of the variables as predictors of travel behavior.

The final models reflect the most appropriate balance among these considerations to achieve the best predictive model with the data available. The final AM and PM peak hour models are shown in Table 7. Both models include the SGF and indicator variables for whether or not the study site is an office land use, is a coffee/donut shop land use, is a multi-use development, or is located within one mile of a major university campus.

Table 7. Final AM Peak Hour and PM Peak Hour Models

Dependent Variable = Natural Logarithm of Ratio of Actual Peak Hour Vehicle Trips to ITE-Estimated Peak Hour Vehicle Trips						
	AM Model			PM Model		
Model Variables	**Coefficient**	**t-value**	**p-value**	**Coefficient**	**t-value**	**p-value**
Smart-Growth Factor	-0.096	-0.857	0.397	-0.155	-1.491	0.143
Office land use (1 = yes, 0 = no)	-0.728	-3.182	0.003	-0.529	-2.558	0.014
Coffee shop land use (1 = yes, 0 = no)	-0.617	-1.677	0.101	-0.744	-2.339	0.024
Multi-use development (1 = yes, 0 = no)	-0.364	-1.561	0.127	-0.079	-0.381	0.705
Within 1 mi. of a university (1 = yes, 0 = no)	-1.002	-2.285	0.028	-0.311	-1.099	0.278
Constant	-0.304	-2.460	0.018	-0.491	-4.469	0.000
Overall Model						
Sample Size (N)	46			50		
Adjusted R^2-Value	0.294			0.290		
F-Value (Test value)	4.74 (p = 0.002)			4.99 (p = 0.001)		

5.1. Modeling Considerations

It is important to remember that the sites used for model development met a specific set of smart-growth criteria, so they are not representative of all types of sites. The models are only appropriate to use in locations that exhibit smart-growth characteristics (as described in the "Recommended Site Criteria for Model Application" section, above). Smart-growth sites tend to produce fewer vehicle trips than ITE baseline sites.

Simple (one-step) ordinary least squares models were tested before the two-step modeling process was applied. A variety of smart-growth contextual variables were used in these one-step ordinary least squares models, but the models were not useful because of the high degree of correlation between the contextual variables. Experimenting with the one-step models helped show that a two-step approach would be most effective for the adjustment methodology.

Small sample sizes (N=46 for AM and N=50 for PM) presented a challenge for modeling. There may be other variables that are related to the ratio of actual to ITE-estimated vehicle trips, but they did not show statistical significance in the limited dataset. For example, several other potential variables suggested by the Review Panel were tested in the models, including an indicator variable representing Northern California versus Southern California and an indicator variable indicating that the site was a residential land use. Neither of these variables showed statistical significance in any models with different combinations of variables, so they were not included in the final models (note that residential-land-use sites can be assessed using this method; they are treated as the base land use type by setting the values for the indicator variables for the other land use categories to zero).

The overall fit for each model was in the range of other multivariate models relating travel behavior to the built environment (the adjusted R^2-value was 0.294 for the AM model and

0.290 for the PM model)[10]. These adjusted R^2-values are lower than many R^2-values in the ITE Trip Generation Manual. However, unlike the models presented here, the model relationships in the Trip Generation Manual are typically between the dependent variable (e.g., number of trips generated during the PM peak hour) and a single explanatory variable (e.g., gross square feet of office space). In addition, the models in the Trip Generation Manual are based on a more homogeneous sample of sites (isolated, single-use, suburban developments) than the sites used in this study. Therefore, it is not appropriate to make a direct comparison between R^2-values in the Trip Generation Manual and the adjusted R^2-values from these models.

The dataset used for modeling included 11 multi-use development sites[11]. Multi-use developments, by definition, are a combination of several individual land uses. These 11 sites increased the size of the dataset for modeling, but the character of trips generated by multi-use developments may be different than trips generated by the other sites (which were each distinct land uses). Therefore, it was important to include the multi-use developments indicator variable in the models since it controls for their influence (even though it had low statistical significance in the PM model). A larger sample size could provide a more precise coefficient estimate for this variable in future versions of these models. Note that this variable is important to include in the model development process to provide accurate (unbiased) parameter estimates, but it is not used when applying the models to estimate vehicle trip generation numbers (i.e., the value of this variable is always set to zero when the models are applied). This is because models are only for single-use sites or single land uses that are a part of multi-use sites. It does not apply to multi-use developments as a whole.

Two of the sites used to develop the AM model and four of the sites used for the PM model were located within one mile of a major university (University of California, Berkeley). Sites in college or university areas (i.e., areas surrounding major colleges or universities where many of the students live on or near the campus) tend to have many smart-growth attributes, but they may also have unique cultural and socioeconomic characteristics that influence travel behavior. Therefore, the indicator variable in the models helps to control for unique trip generation characteristics in university areas.

We also tested a version of the PM model with an indicator variable for study sites that were retail land uses in place of the indicator variable for multi-use development. This model had a slightly better overall fit (adjusted R^2 = 0.304) than the final model shown above (adjusted R^2 = 0.290). However, the coefficient estimates for the other variables in this alternative model

[10] The adjusted R^2-value for an ordinary least squares model is similar to R^2, but it controls for differences in the number of variables (i.e., the regular R^2-value is less useful because it increases when more variables are added to a model equation, even if these variables add little explanatory power to the model).

[11] Sources of data for these sites included 1) EPA MXD Study: "Trip Generation Tool for Mixed-Use Developments." http://www.epa.gov/smartgrowth/mxd_tripgeneration.html; 2) SANDAG MXD Study: "Trip Generation for Smart Growth: Planning Tools for the San Diego Region" SANDAG, June 2010. http://www.sandag.org/tripgeneration; and 3) Fehr & Peers: Multi- or mixed-use sites for which Fehr & Peers collected cordon count data (via pneumatic tubes).

were very similar to the final model and it had the disadvantage of not controlling for the unique aspects of multi-use development travel behavior.

Several sources of variability in trip generation were not possible to control through the modeling process. These sources include differences in overall activity levels at each study site and differences in data collection methods.

- Some sites may have had high levels of economic activity (e.g., a popular shopping district). In these cases, the overall number of trips generated by all modes, including vehicles, would tend to be higher than the typical trip generation numbers predicted by ITE (because ITE rates are based on a sample of sites throughout the country and are assumed to represent average economic activity). In contrast, some sites may have been somewhat depressed economically. This concern was controlled, to a certain degree, by accounting for percent occupancy of residential and office sites when estimating trip generation, but overall trip rates could be impacted by unemployment or low sales. This limitation also applies to ITE trip generation estimates.
- ITE data collection methods assume that off-site parking is minimal and do not count trips that involve walking to or from off-site parking (i.e., parking that is separated from the studied land use by some type of public right of way). Of the 2,764 recorded automobile trips that used parking in UC Davis's spring 2012 data collection, only 139 (5.0%) involved walking to or from off-site parking. Most off-site parking reported was actually at the official parking structure for the site (e.g., Convention Plaza, 180 Grand Avenue) or on the street adjacent to the site. Note that any error created by including off-site parking vehicle trips made the comparison more conservative, because this error would have increased the actual number of vehicle trips relative to ITE-estimated vehicle trips.
- This study also expanded the ITE definition of the morning peak and afternoon peak hour periods from two hours to three. Identifying the one-hour period with the highest number of trips from 7 a.m. to 10 a.m. and 4 p.m. to 7 p.m. captured higher numbers of peak hour vehicle trips at some sites than would have been documented otherwise.

Because ITE methods do not account for trips to and from individual land uses within buildings, the four targeted land uses with internal doorway counts included more overall person trips than would have been counted using the ITE approach. While this approach influenced the overall person trip generation mode share at these targeted land uses, it did not add vehicle trips.

The next edition of the *ITE Trip Generation Handbook* is likely to support a person-trip-based approach for trip generation analysis. Therefore, the research team considered using percent non-vehicle trips as the dependent variable in the models. This would allow practitioners to use the models as a part of a person-trip approach by: 1) calculating standard ITE vehicle trip generation estimates; 2) applying adjustments for both a) non-automobile mode share (using the models) and b) vehicle occupancy (using other assumptions) to get actual vehicle trips. However, 16 sites in the dataset only had vehicle trip counts and did not include trips by mode, so they would have been removed from the analysis. This exclusion of sites would have made the dataset too small to develop reliable models.

6. Model Application

The models are straightforward to apply. The following example illustrates how the PM model would be applied at the Central City Association of Los Angeles office building, one of the sites set aside for validation. There are two steps in the process: 1) calculate the SGF and 2) apply the model equation given the site conditions.

The first step is to calculate the SGF based on the characteristics of the site (Table 8). Using the example, there are 13,072 people living within a 0.5-mile, straight-line radius and 74,881 jobs within a 0.5-mile, straight-line radius of the Central City Association of Los Angeles office building. The values for the example site variables in Table 8 are standardized based on the mean and standard deviation of each variable from the set of 50 sites used to develop the PM model[12]. For example, the residential population variable value at the example site (13.072) is standardized using the mean (9.718) and standard deviation (6.811) of this variable from the 50 sites used to develop the model (listed in Table 6):

Standardized value of residential population variable = (13.072 – 9.718)/6.811 = 0.492

The SGF is the sum of the coefficient multiplied by the standardized value for all eight variables (Table 8). For the example office building study site, the SGF is 1.723.

[12] A value is standardized by taking the value of the that site and subtracting the mean value from the 50 sites then dividing by the standard deviation of variable from 50 sites.

Table 8. Example Smart-Growth Factor Calculation: Central City Association of LA Office Site

Variable	Coefficient	Value	Standard Value[1]	Factor
Residential population within a 0.5-mile, straight-line radius (000s)[2]	0.099	13.072	0.492	0.049
Jobs within a 0.5-mile, straight-line radius (000s)[3]	0.324	74.881	1.690	0.548
Straight-line distance to center of central business district (CBD) (miles)[4]	-0.138	0.089	-0.807	0.111
Average building setback distance from sidewalk (feet)[5]	-0.167	0.000	-0.657	0.110
Metered on-street parking within a 0.1-mile, straight-line radius (1=yes, 0=no)[6]	0.184	1.000	0.776	0.143
Individual PM peak-hour buses passing within a 0.25-mile, straight-line radius[7]	0.227	208.000	3.237	0.735
Individual PM peak-hour trains passing within a 0.5-mile, straight-line radius[8]	0.053	4.000	-0.232	-0.012
Proportion of site area covered by surface parking lots (0.00 to 1.00)[9]	-0.080	0.000	-0.506	0.041
Smart-Growth Factor (SGF)				**1.723**

Notes:
1. This coefficient is applied to the standardized version of the variable. The standardized value is calculated using the mean and standard deviation of variable values from the 50 PM analysis sites.
2. The 0.5-mile, straight-line radius is measured from the center of the site. This measure was calculated in GIS for model development using US Census block group data (2010), but it is also possible to estimate the population within 0.5-miles from online sources.
3. The 0.5-mile, straight-line radius is measured from the center of the site. This measure was calculated in GIS for model development using US Census block group data (2010), but it is also possible to estimate the employment within 0.5-miles from online sources.
4. Straight-line distance from center of study site to center of the regional central business district (CBD). Example regional CBDs include Los Angeles, San Diego, San Francisco, Sacramento, and Oakland. Sub-regional centers such as Walnut Creek or Pasadena are not classified as CBDs.
5. Average building setback is the average straight-line distance to the sidewalk from all major building entrances (feet). Major entrances include the main pedestrian entrance and automobile garage entrances.
6. Metered parking only includes metered on-street parking. Metered off-street surface lots or parking structures are not included. The 0.1-mile, straight-line radius is measured from the center of the site.
7. Number of individual bus stop locations on all bus lines that pass within any part of a 0.25-mile radius around the study site during a typical weekday PM peak hour. For example, consider a site that has two bus stops, A and B within a straight-line 0.25-mile radius from the center of the site. During the weekday PM peak hour, bus stop A serves bus lines 17, 28, and 52. Meanwhile, bus stop B serves bus lines 21, 28, and 52. In this case, the total stop locations on all bus lines that pass within any part of a 0.25-mile radius around the study site during a typical weekday PM peak hour is 6 (bus line 17 has one stop location, bus line 21 has one stop location, bus line 28 has two stop locations, and bus line 52 has two stop locations). The frequency of bus service on each line is not considered. PM peak-hour train line stops are calculated using a similar method.
8. Number of individual train stop locations on all train lines that pass within any part of a 0.5-mile radius around the study site during a typical weekday PM peak hour. For an example, see the bus stop location description.
9. Proportion of site surface area covered by surface parking lots does not include surface area covered by parking structures. Therefore, sites that only have parking garages should be given a value of 0.00.

The second step is to calculate ratio of actual vehicle trips to ITE-based vehicle trip estimates using the PM model equation:

$$\textit{Actual vehicle trips/ITE vehicle trips} = e^{(-0.155\times1.723 - 0.529\times1 - 0.744\times0 - 0.079\times0 - 0.311\times0 - 0.491)} = 0.276$$

If existing ITE methods estimated 200 PM peak hour vehicle trips, then the adjusted number of vehicle trips estimated by the model would be calculated as:

Model-adjusted estimate of vehicle trips = 0.276 × 200 = 55

An office project with a SGF equal to the highest value in the sample of study sites, 2.41, would have a ratio of model to ITE-estimated vehicle trips of 0.248 (i.e., 75% reduction in ITE-estimated vehicle trips), while an office project with a SGF equal to the lowest value in the sample, -1.44, would have a ratio of 0.451. A residential project with the lowest SGF in the sample would have a ratio of 0.765 (i.e., a 23% reduction in ITE-estimated vehicle trips).

The models can also be used to test the impact of changing contextual variables. However, single-variable sensitivity tests are not realistic for this type of two-step model. This is because the individual components of the SGF variable are correlated. A change in one SGF component would be associated with changes in other SGF components (e.g., it is likely that an increase in residential density would be accompanied by other changes, such as increased transit service and reduced building setbacks, so the overall impact would need to be calculated by quantifying the related changes to all SGF component variables).

A hypothetical sensitivity test example is shown below. This example illustrates the changes that could occur if a city planned to double the number of jobs in a district surrounding a mid- to high-density residential site. Table 9 shows the baseline values for the SGF. These baseline SGF values produce a PM-peak hour vehicle-trip generation adjustment factor of 0.64 (the model output predicts that there would be 36% fewer vehicle trips than estimated by ITE).

Table 9. Hypothetical Residential Site Example: Baseline Smart-Growth Factor Values

Variable	Value
Residential population within a 0.5-mile, straight-line radius (000s)[1]	20.00
Jobs within a 0.5-mile, straight-line radius (000s)[2]	10.00
Straight-line distance to center of central business district (CBD) (miles)[3]	1.00
Average building setback distance from sidewalk (feet)[4]	50.00
Metered on-street parking within a 0.1-mile, straight-line radius (1=yes, 0=no)[5]	0.00
Individual PM peak-hour bus line stops passing within a 0.25-mile, straight-line radius[6]	20.00
Individual PM peak-hour train line stops passing within a 0.5-mile, straight-line radius[7]	4.00
Proportion of site area covered by surface parking lots (0.00 to 1.00)[8]	0.20

Notes:

1. The 0.5-mile, straight-line radius is measured from the center of the site. This measure was calculated in GIS for model development using US Census block group data (2010), but it is also possible to estimate the population within 0.5-miles from online sources.
2. The 0.5-mile, straight-line radius is measured from the center of the site. This measure was calculated in GIS for model development using US Census block group data (2010), but it is also possible to estimate the employment within 0.5-miles from online sources.
3. Straight-line distance from center of study site to center of the regional central business district (CBD). Example regional CBDs include Los Angeles, San Diego, San Francisco, Sacramento, and Oakland. Sub-regional centers such as Walnut Creek or Pasadena are not classified as CBDs.
4. Average building setback is the average straight-line distance to the sidewalk from all major building entrances (feet). Major entrances include the main pedestrian entrance and automobile garage entrances.
5. Metered parking only includes metered on-street parking. Metered off-street surface lots or parking structures are not included. The 0.1-mile, straight-line radius is measured from the center of the site.
6. Number of individual bus stop locations on all bus lines that pass within any part of a 0.25-mile radius around the study site during a typical weekday PM peak hour. For example, consider a site that has two bus stops, A and B within a straight-line 0.25-mile radius from the center of the site. During the weekday PM peak hour, bus stop A serves bus lines 17, 28, and 52. Meanwhile, bus stop B serves bus lines 21, 28, and 52. In this case, the total stop locations on all bus lines that pass within any part of a 0.25-mile radius around the study site during a typical weekday PM peak hour is 6 (bus line 17 has one stop location, bus line 21 has one stop location, bus line 28 has two stop locations, and bus line 52 has two stop locations). The frequency of bus service on each line is not considered. PM peak-hour train line stops are calculated using a similar method.
7. Number of individual train stop locations on all train lines that pass within any part of a 0.5-mile radius around the study site during a typical weekday PM peak hour. For an example, see the bus stop location description.
8. Proportion of site surface area covered by surface parking lots does not include surface area covered by parking structures. Therefore, sites that only have parking garages should be given a value of 0.00.

If the employment variable is doubled from 10,000 to 20,000 jobs in isolation, the adjustment factor will decrease to 0.63, which is only a slight reduction from 0.64. However, it is likely that doubling employment density would be accompanied by increasing residential density, decreasing building setbacks, metering street parking, increasing transit service, and reducing surface parking lot coverage, producing the SGF values shown in Table 10. Based on these new SGF values, the adjustment factor would decrease to 0.54, which is a 16% reduction from 0.64. This result is more realistic than if the model sensitivity is evaluated by only changing the employment variable.

Table 10. Hypothetical Residential Site Example: New Smart-Growth Factor Values

Variable	Value
Residential population within a 0.5-mile, straight-line radius (000s)[1]	40.00
Jobs within a 0.5-mile, straight-line radius (000s)[2]	20.00
Straight-line distance to center of central business district (CBD) (miles)[3]	1.00
Average building setback distance from sidewalk (feet)[4]	10.00
Metered on-street parking within a 0.1-mile, straight-line radius (1=yes, 0=no)[5]	1.00
Individual PM peak-hour bus line stops passing within a 0.25-mile, straight-line radius[6]	40.00
Individual PM peak-hour train line stops passing within a 0.5-mile, straight-line radius[7]	6.00
Proportion of site area covered by surface parking lots (0.00 to 1.00)[8]	0.00

Notes:

1. The 0.5-mile, straight-line radius is measured from the center of the site. This measure was calculated in GIS for model development using US Census block group data (2010), but it is also possible to estimate the population within 0.5-miles from online sources.
2. The 0.5-mile, straight-line radius is measured from the center of the site. This measure was calculated in GIS for model development using US Census block group data (2010), but it is also possible to estimate the employment within 0.5-miles from online sources.
3. Straight-line distance from center of study site to center of the regional central business district (CBD). Example regional CBDs include Los Angeles, San Diego, San Francisco, Sacramento, and Oakland. Sub-regional centers such as Walnut Creek or Pasadena are not classified as CBDs.
4. Average building setback is the average straight-line distance to the sidewalk from all major building entrances (feet). Major entrances include the main pedestrian entrance and automobile garage entrances.
5. Metered parking only includes metered on-street parking. Metered off-street surface lots or parking structures are not included. The 0.1-mile, straight-line radius is measured from the center of the site.
6. Number of individual bus stop locations on all bus lines that pass within any part of a 0.25-mile radius around the study site during a typical weekday PM peak hour. For example, consider a site that has two bus stops, A and B within a straight-line 0.25-mile radius from the center of the site. During the weekday PM peak hour, bus stop A serves bus lines 17, 28, and 52. Meanwhile, bus stop B serves bus lines 21, 28, and 52. In this case, the total stop locations on all bus lines that pass within any part of a 0.25-mile radius around the study site during a typical weekday PM peak hour is 6 (bus line 17 has one stop location, bus line 21 has one stop location, bus line 28 has two stop locations, and bus line 52 has two stop locations). The frequency of bus service on each line is not considered. PM peak-hour train line stops are calculated using a similar method.
7. Number of individual train stop locations on all train lines that pass within any part of a 0.5-mile radius around the study site during a typical weekday PM peak hour. For an example, see the bus stop location description.
8. Proportion of site surface area covered by surface parking lots does not include surface area covered by parking structures. Therefore, sites that only have parking garages should be given a value of 0.00.

However, we recognize that for practical application, analysts will be interested to see how the models respond to changes in individual components of the SGF. Analysts will want to see that each individual component responds in the correct direction (i.e., characteristics that support smart-growth will lead to greater reductions in vehicle trips) and that the relative contribution of each specific component makes intuitive sense (e.g., adding a train line stop will lead to a greater reduction in vehicle trips than adding a bus line stop). Upon review, each individual component of the SGF does respond in the correct direction. Yet, some components have very small impacts on the overall SGF (e.g., distance to CBD, train line stops within 0.5 miles), and the relative impact of rail line stops is about the same as bus line stops. Improving the fine-grained accuracy of individual components of the SGF is most likely beyond what is possible to derive from the existing dataset. These micro-level refinements are important to pursue through future research.

7. Model Validation

Eleven sites with AM peak hour trip data and 13 sites with PM peak hour trip data were not used to develop the models. They were reserved to provide data for model validation. Validation was done by comparing the ratio of actual to ITE-estimated vehicle trips from the models with the observed data at the validation sites (Table 11 and Figure 1 for AM; Table 12 and Figure 2 for PM). This comparison showed that the models predicted the smart-growth adjustment accurately at some validation sites (the model ratio was within 50% of the observed ratio at seven of the 11 AM sites and seven of 13 PM sites) but lacked accuracy at other sites. In general, the models overestimated the ratio of actual to ITE vehicle trips at sites with the least accurate model predictions (i.e., actual trip data showed that sites had fewer vehicle trips than the model predicted; most data points in Figure 1 and Figure 2 are below the diagonal line which indicates where model values would have equaled observed values). Thus, the models produced conservative adjustments relative to ITE-based trip estimates.

Table 11. AM Model Validation

ID	Site Name	City	General Land Use Category	AM Model Output (Actual/ITE)	Observed AM (Actual/ITE)	AM Model-Observed
113.1	Central City Association of LA	Los Angeles, CA	Office	0.30	0.41	-0.10
114.1	Horizon	San Diego, CA	Residential	0.72	0.23	0.49
115.1	Atria	San Diego, CA	Residential	0.72	0.82	-0.10
120.1	Archstone Fox Plaza	San Francisco, CA	Residential	0.65	0.13	0.52
122.1	Bong Su	San Francisco, CA	Restaurant	0.64	0.18	0.47
142.1	Berkeleyan Apartments	Berkeley, CA	Residential	0.27	0.18	0.08
144.2	Acton Courtyard	Berkeley, CA	Restaurant	0.74	0.04	0.70
201.2	343 Sansome	San Francisco, CA	Coffee	0.32	0.23	0.09
215.1	Broadway Grand	Oakland, CA	Residential	0.71	0.71	0.00
220.2	Park Tower	Sacramento, CA	Coffee	0.34	0.40	-0.07
222.2	Convention Plaza	San Francisco, CA	Coffee	0.33	0.29	0.04

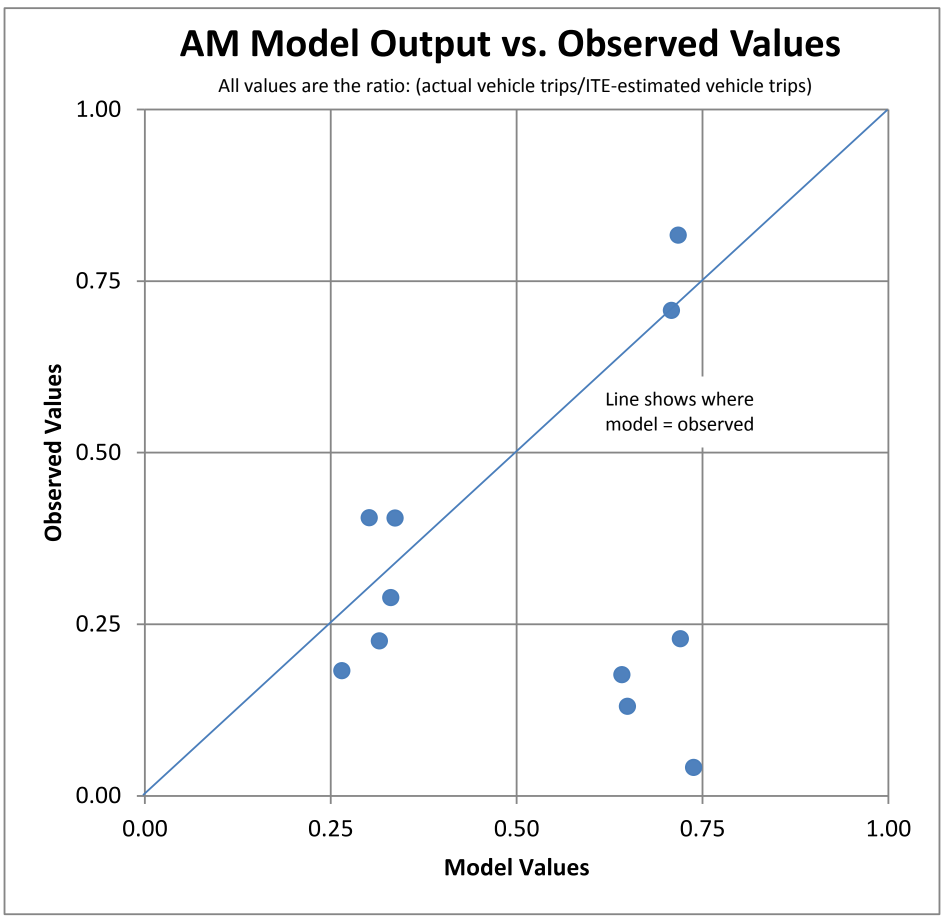

Figure 1. AM Model Validation Plot

Table 12. PM Model Validation

ID	Site Name	City	General Land Use Category	PM Model Output	Observed PM Actual/ITE	PM Model-Observed
113.1	Central City Association of LA	Los Angeles, CA	Office	0.28	0.32	-0.05
114.1	Horizon	San Diego, CA	Residential	0.59	0.35	0.24
115.1	Atria	San Diego, CA	Residential	0.58	0.62	-0.03
120.1	Archstone Fox Plaza	San Francisco, CA	Residential	0.50	0.16	0.34
122.1	Bong Su	San Francisco, CA	Restaurant	0.49	0.62	-0.13
142.1	Berkeleyan Apartments	Berkeley, CA	Residential	0.43	0.18	0.25
143.1	Touriel Building	Berkeley, CA	Residential	0.42	0.30	0.12
144.2	Acton Courtyard	Berkeley, CA	Restaurant	0.61	0.23	0.38
146.1	Bachenheimer Building	Berkeley, CA	Residential	0.42	0.08	0.34
208.1	Paseo Colorado	Pasadena, CA	Retail	0.60	0.41	0.19
215.1	Broadway Grand	Oakland, CA	Residential	0.57	0.52	0.05
220.2	Park Tower	Sacramento, CA	Coffee	0.22	0.28	-0.06
222.2	Convention Plaza	San Francisco, CA	Coffee	0.22	0.33	-0.12

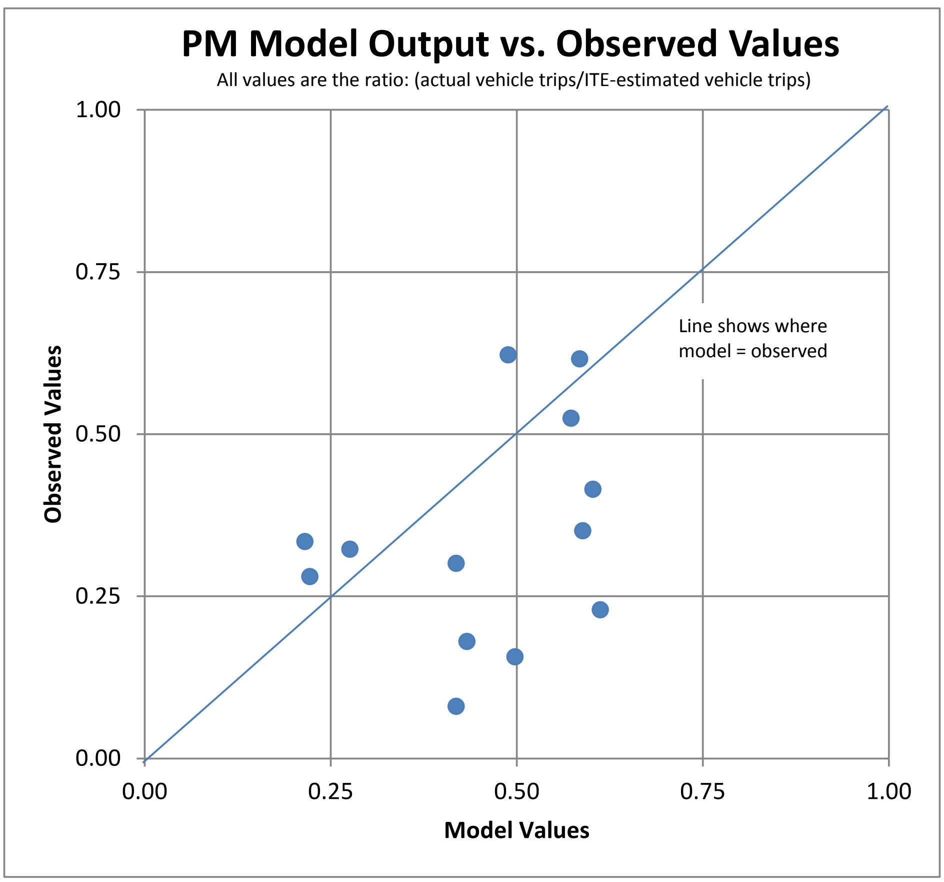

Figure 2. PM Model Validation Chart

8. Conclusion

This memorandum presents models that can be used to adjust ITE vehicle trip generation estimates at smart-growth sites based on specific contextual characteristics. One model applies to the AM peak hour and the other applies to the PM peak hour. It is likely that the small-sample models were not able to account for all of the complex variation in sites, including different levels of economic activity at particular locations.

The models are based on actual vehicle trip generation data collected in Spring 2012 and in previous studies at California smart-growth study sites. For sites where the models did not predict vehicle trip generation accurately, validation checks showed that the models estimated "conservative" trip reductions (i.e., overestimated vehicle trips compared to actual counts at most validation sites). While the models do not predict perfectly, they represent a significant step forward in developing methods to adjust ITE trip generation estimates in locations with smart-growth characteristics. Future studies should improve these models by increasing the sample of sites used for model development and validation.

9. References

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APPENDIX A: Sites Used for Model Development and Validation

General Site Information						Model and Validation Datasets (X indicates site was included)				General Land Use Category (specific ITE Land Use Code numbers given below)						Size and Occupancy (numbers in italics are estimated)				
ID	Region	Site Name	Primary Address	City	Source	AM Model Development	AM Validation	PM Model Development	PM Validation	Mid- to High-Density Residential	Office	Commercial Retail Goods	Coffee/Donut Shop	Other Specific Use	Mixed Use Site	Residential Units	Residential Occupancy	Office Gross Square Feet (GSF)	Office Occupancy	Retail Gross Square Feet (GSF)
102.1	Los Angeles	Jamboree Center	1 Park Plaza	Irvine, CA	EPA MXD Study	X		X							X					
103.1	Los Angeles	Park Place	3131 Michelson Drive	Irvine, CA	EPA MXD Study	X		X							X					
104.1	Los Angeles	The Villages	38 Prism Drive	Irvine, CA	EPA MXD Study	X		X							X					
105.1	San Diego	Rio Vista Station Village	2185 Station Village Way	San Diego, CA	SANDAG MXD Study	X		X							X					
106.1	San Diego	La Mesa Village Plaza	4700 Spring Street	La Mesa, CA	SANDAG MXD Study	X		X							X					
107.1	San Diego	Uptown Center	1270 Cleveland Avenue	San Diego, CA	SANDAG MXD Study	X		X							X					
108.1	San Diego	The Village at Morena Linda Vista	5395 Napa Street	San Diego, CA	SANDAG MXD Study	X		X							X					
109.1	San Diego	Hazard Center	7676 Hazard Center Drive	San Diego, CA	SANDAG MXD Study	X		X							X					
110.1	San Diego	Heritage Center at Otay Ranch	1394 E. Palomar Street	Chula Vista, CA	SANDAG MXD Study	X		X							X					
112.1	San Francisco	1388 Sutter Street	1388 Sutter Street	San Francisco, CA	Caltrans Infill Study	X		X			710							120,000	100%	
115.2	San Diego	Atria	101 Market Street	San Diego, CA	Caltrans Infill Study	X		X					936							1,250
116.1	Los Angeles	10351 Santa Monica Boulevard	10351 Santa Monica Boulevard	Los Angeles, CA	Caltrans Infill Study	X		X			710							101,495	89%	
117.1	Los Angeles	Wilshire Pacific Plaza	12301 Wilshire Boulevard	Los Angeles, CA	Caltrans Infill Study	X		X			710							105,977	80%	
118.1	Los Angeles	Archstone Santa Monica on Main	2000 Main Street	Santa Monica, CA	Caltrans Infill Study	X		X		223						133	93%			
119.1	Los Angeles	Archstone Pasadena	25 South Oak Knoll Avenue	Pasadena, CA	Caltrans Infill Study	X		X		223						120	95%			
121.1	San Francisco	Pazzia Caffe and Trattoria	337 3rd Street	San Francisco, CA	Caltrans Infill Study	X		X						931						3,000
123.1	East Bay	Mission Wells	39128 Guardino Drive	Fremont, CA	TCRP Report 128	X		X		220						391	*100%*			
124.1	East Bay	Montelena Apartment Homes	655 Tennyson Road	Hayward, CA	TCRP Report 128	X		X		220						188	*100%*			
125.1	East Bay	Park Regency	3128 Oak Road	Walnut Creek, CA	TCRP Report 128	X		X		220						854	*100%*			
126.1	East Bay	Verandas	33 Union Square	Union City, CA	TCRP Report 128	X		X		220						282	*100%*			
127.1	East Bay	Wayside Commons	3183 Wayside Plaza	Walnut Creek, CA	TCRP Report 128	X		X		230						156	*100%*			
128.1	San Francisco	Larkspur Landing	2001 Larkspur Landing Circle	Larkspur, CA	Fehr & Peers	X		X							X					
130.1	East Bay	Bay Street	5616 Bay Street	Emeryville, CA	Fehr & Peers	X		X							X					
136.1	East Bay	Fine Arts Building	2110 Haste Street	Berkeley, CA	Caltrans Infill Study	X		X		223						100	100%			
142.2	East Bay	Berkeleyan Apartments	1910 Oxford Street	Berkeley, CA	Caltrans Infill Study	X		X					936							4,500
144.1	East Bay	Acton Courtyard	1370 University Avenue	Berkeley, CA	Caltrans Infill Study	X		X		223						71	100%			
201.1	San Francisco	343 Sansome	343 Sansome Stret	San Francisco, CA	UCD Data Collection	X		X			710							256,985	89%	
202.1	East Bay	Oakland City Center	1333 Broadway	Oakland, CA	UCD Data Collection	X		X			710							239,821	80%	
204.1	Los Angeles	Sakura Crossing	235 S. San Pedro Street	Los Angeles, CA	UCD Data Collection	X		X		223						230	96%			
205.1	Los Angeles	Artisan on 2nd	601 E. Second Street	Los Angeles, CA	UCD Data Collection	X		X		223						118	96%			
206.1	Los Angeles	Victor on Venice	10001 Venice Boulevard	Los Angeles, CA	UCD Data Collection	X		X		223						116	95%			
209.1	East Bay	The Sierra	311 Oak Street	Oakland, CA	UCD Data Collection	X		X		223						224	98%			
210.1	East Bay	180 Grand Avenue	180 Grand Avenue	Oakland, CA	UCD Data Collection	X		X			710							277,789	63%	
211.1	Los Angeles	Archstone at Del Mar Station	265 Arroyo Parkway	Pasadena, CA	UCD Data Collection	X		X		223						235	94%			
212.1	East Bay	Terraces at Emery Station	5855 Horton Street	Emeryville, CA	UCD Data Collection	X		X		223						101	100%			
213.1	Los Angeles	Holly Street Village	151 E. Holly Street	Pasadena, CA	UCD Data Collection	X		X		223						374	95%			
214.1	East Bay	Emery Station East	5885 Hollis Street	Emeryville, CA	UCD Data Collection	X		X			710							247,619	*95%*	
215.2	East Bay	Broadway Grand	438 W. Grand Avenue	Oakland, CA	UCD Data Collection	X		X					936							*1,300*
216.1	Los Angeles	Terraces Apartment Homes	375 E. Green Street	Pasadena, CA	UCD Data Collection	X		X		223						276	94%			
217.1	San Francisco	181 Second Avenue	181 2nd Avenue	San Mateo, CA	UCD Data Collection	X		X			710							50,600	99%	
218.1	San Francisco	Argenta	1 Polk Street	San Francisco, CA	UCD Data Collection	X		X		222						187	95%			
219.1	San Francisco	Charles Schwab Building	211 Main Street	San Francisco, CA	UCD Data Collection	X		X			710							417,245	77%	
220.1	Sacramento	Park Tower	980 9th Street	Sacramento, CA	UCD Data Collection	X		X			710							462,476	90%	
221.1	Sacramento	Fremont Building	1501 16th Street	Sacramento, CA	UCD Data Collection	X		X		223						69	96%			
222.1	San Francisco	Convention Plaza	201 3rd Street	San Francisco, CA	UCD Data Collection	X		X			710							323,000	96%	
207.1	Los Angeles	Pegasus	612 S. Flower Street	Los Angeles, CA	UCD Data Collection	X				222						322	96%			
111.1	East Bay	Chain Clothing Store	1333 Broadway	Oakland, CA	Caltrans Infill Study			X				820								11,000
145.1	East Bay	Gaia Building	2116 Allston Way	Berkeley, CA	Caltrans Infill Study			X		223						99	99%			
146.2	East Bay	Bachenheimer Building	2111 University Avenue	Berkeley, CA	Caltrans Infill Study			X				820								3,000
203.1	East Bay	Fruitvale Station	3100 E. 9th Street	Oakland, CA	UCD Data Collection			X				867								30,037
223.1	Sacramento	Park Plaza	1303 J Street	Sacramento, CA	UCD Data Collection			X			710							72,649	88%	
113.1	Los Angeles	Central City Association of Los Angeles	626 Wilshire Boulevard	Los Angeles, CA	Caltrans Infill Study		X		X		710							138,542	98%	
114.1	San Diego	Horizon	555 Front Street	San Diego, CA	Caltrans Infill Study		X		X	232						211	100%			
115.1	San Diego	Atria	101 Market Street	San Diego, CA	Caltrans Infill Study		X		X	230						149	100%			
120.1	San Francisco	Archstone Fox Plaza	1390 Market Street	San Francisco, CA	Caltrans Infill Study		X		X	222						443	95%			
122.1	San Francisco	Bong Su	311 3rd Street	San Francisco, CA	Caltrans Infill Study		X		X					931						6,000
142.1	East Bay	Berkeleyan Apartments	1910 Oxford Street	Berkeley, CA	Caltrans Infill Study		X		X	223						56	100%			
144.2	East Bay	Acton Courtyard	1370 University Avenue	Berkeley, CA	Caltrans Infill Study		X		X					939						5,000
215.1	East Bay	Broadway Grand	438 W. Grand Avenue	Oakland, CA	UCD Data Collection		X		X	223						130	82%			
220.2	Sacramento	Park Tower	980 9th Street	Sacramento, CA	UCD Data Collection		X		X				936							1,652
222.2	San Francisco	Convention Plaza	201 3rd Street	San Francisco, CA	UCD Data Collection		X		X				936							1,556
201.2	San Francisco	343 Sansome	343 Sansome Stret	San Francisco, CA	UCD Data Collection		X						936							1,097
143.1	East Bay	Touriel Building	2004 University Avenue	Berkeley, CA	Caltrans Infill Study				X	223						35	97%			
146.1	East Bay	Bachenheimer Building	2111 University Avenue	Berkeley, CA	Caltrans Infill Study				X	223						44	100%			
208.1	Los Angeles	Paseo Colorado	280 E. Colorado Boulevard	Pasadena, CA	UCD Data Collection				X			820								497,564
					Totals by Category:	**46**	**11**	**50**	**13**	**28**	**13**	**4**	**6**	**3**	**11**					

ID	Data for Dependent Variables								Explanatory Variables								
ID	AM Peak Hour Vehicle Trips	PM Peak Hour Vehicle Trips	ITE AM Peak Hour Vehicle Trips	ITE PM Peak Hour Vehicle Trips	Actual/ITE AM Vehicle Trips	Ln(Actual/ITE AM Vehicle Trips)	Actual/ITE PM Vehicle Trips	Ln(Actual/ITE PM Vehicle Trips)	% of site covered by surface parking	Number of Jobs within 0.5 mi (in 1000s)	Population within 0.5 mi (in 1000s)	Distance to CBD (mi)	Average building setback (ft)	Metered on-street parking within 0.1 mi	Peak hour bus line stops within 0.25 mi	Peak hour train line stops within 0.5 mi	Within 1 mile of a University
102.1	3125	3513	3893	4212	0.80	-0.22	0.83	-0.18	0.10	10.71	2.60	35.02	325	0	11.00	0.00	0
103.1	1295	1676	3068	3289	0.42	-0.86	0.51	-0.67	0.30	10.84	1.47	35.20	197	0	9.00	0.00	0
104.1	664	605	757	877	0.88	-0.13	0.69	-0.37	0.00	5.74	0.79	40.10	247	0	17.00	0.00	0
105.1	280	452	650	757	0.43	-0.84	0.60	-0.52	0.00	6.82	3.86	4.32	285	0	3.00	2.00	0
106.1	302	434	456	518	0.66	-0.41	0.84	-0.18	0.15	3.84	4.86	8.80	179	1	9.00	1.00	0
107.1	638	1560	882	1203	0.72	-0.32	1.30	0.26	0.15	16.31	9.39	2.51	10	0	19.00	0.00	0
108.1	315	361	693	774	0.45	-0.79	0.47	-0.76	0.35	5.23	3.76	4.14	98	0	5.00	1.00	0
109.1	614	978	1575	1891	0.39	-0.94	0.52	-0.66	0.20	8.44	3.50	3.97	93	0	2.00	2.00	0
110.1	667	673	485	697	1.38	0.32	0.97	-0.04	0.50	0.67	5.61	11.40	182	0	4.00	0.00	0
112.1	112	85	186	179	0.60	-0.50	0.48	-0.74	0.00	19.01	42.11	1.07	0	1	73.00	5.00	0
115.2	47	8	147	51	0.32	-1.14	0.16	-1.84	0.00	31.19	11.34	0.31	0	1	9.00	3.00	0
116.1	20	35	140	135	0.14	-1.97	0.26	-1.35	0.00	14.96	7.47	9.67	0	1	15.00	0.00	0
117.1	39	61	131	126	0.30	-1.22	0.48	-0.73	0.15	7.30	13.73	12.31	0	1	12.00	0.00	0
118.1	24	24	37	48	0.65	-0.43	0.50	-0.69	0.00	4.43	6.32	13.71	0	1	39.00	0.00	0
119.1	30	29	34	44	0.89	-0.12	0.64	-0.44	0.05	21.02	10.08	9.60	0	0	52.00	0.00	0
121.1	8	7	17	22	0.46	-0.78	0.32	-1.16	0.00	81.86	13.83	0.42	0	1	112.00	18.00	0
123.1	188	190	215	262	0.87	-0.13	0.73	-0.32	0.02	3.99	7.18	23.66	144	0	4.00	2.00	0
124.1	32	38	103	126	0.31	-1.17	0.30	-1.20	0.05	0.49	5.63	16.56	223	0	22.00	2.00	0
125.1	290	371	470	572	0.62	-0.48	0.65	-0.43	0.05	5.42	6.47	14.53	524	0	14.00	1.00	0
126.1	54	103	155	189	0.35	-1.06	0.55	-0.61	0.05	1.26	7.90	20.37	252	0	26.00	2.00	0
127.1	33	53	69	81	0.48	-0.73	0.65	-0.43	0.02	5.66	6.74	14.73	175	0	13.00	1.00	0
128.1	956	1278	*1916*	*2443*	0.50	-0.70	0.52	-0.65	0.30	2.13	1.53	12.48	202	0	3.00	0.00	0
130.1	288	1201	*1236*	*3019*	0.23	-1.46	0.40	-0.92	0.00	8.46	3.75	2.35	0	1	6.00	0.00	0
136.1	10	10	30	39	0.34	-1.08	0.26	-1.35	0.00	12.34	16.54	4.18	0	1	27.00	2.00	1
142.2	59	26	528	183	0.11	-2.19	0.14	-1.95	0.00	10.16	12.78	4.78	0	1	47.00	2.00	1
144.1	12	9	21	28	0.57	-0.56	0.34	-1.08	0.00	2.23	10.87	4.58	0	1	21.00	2.00	0
201.1	72	58	355	341	0.20	-1.59	0.17	-1.76	0.00	136.40	18.49	0.43	5	1	143.00	59.00	0
202.1	100	59	297	286	0.34	-1.09	0.21	-1.58	0.00	46.44	14.06	0.03	0	1	137.00	6.00	0
204.1	77	61	66	86	1.16	0.15	0.71	-0.34	0.00	65.97	13.31	0.76	13	1	24.00	1.00	0
205.1	32	31	34	44	0.94	-0.06	0.70	-0.35	0.15	26.98	7.06	1.07	28	1	9.00	1.00	0
206.1	44	50	33	43	1.32	0.28	1.17	0.16	0.00	5.27	15.81	8.50	0	1	18.00	0.00	0
209.1	50	61	66	86	0.76	-0.27	0.72	-0.33	0.00	12.89	5.98	0.76	0	0	13.00	15.00	0
210.1	80	65	271	261	0.29	-1.23	0.25	-1.39	0.00	19.23	13.22	0.64	3	1	41.00	3.00	0
211.1	50	46	66	86	0.75	-0.28	0.53	-0.63	0.00	16.38	7.66	8.89	27	1	34.00	2.00	0
212.1	100	87	30	39	3.29	1.19	2.21	0.80	0.00	10.31	6.87	2.69	5	0	5.00	13.00	0
213.1	108	94	107	139	1.01	0.01	0.68	-0.39	0.00	22.71	7.95	9.24	209	1	53.00	2.00	0
214.1	133	123	365	351	0.36	-1.01	0.35	-1.05	0.00	9.62	7.48	2.69	8	0	5.00	13.00	0
215.2	90	36	152	53	0.59	-0.53	0.69	-0.38	0.00	20.48	11.72	0.54	2	1	56.00	3.00	0
216.1	54	37	78	101	0.69	-0.37	0.36	-1.02	0.00	23.34	9.93	9.26	14	1	9.00	2.00	0
217.1	92	85	77	74	1.19	0.17	1.15	0.14	0.00	6.98	10.92	15.91	7	1	0.00	6.00	0
218.1	25	22	53	62	0.47	-0.76	0.35	-1.05	0.00	61.46	25.70	1.09	0	1	83.00	21.00	0
219.1	59	43	498	479	0.12	-2.13	0.09	-2.41	0.00	87.33	10.05	0.60	27	1	97.00	40.00	0
220.1	319	312	645	620	0.49	-0.70	0.50	-0.69	0.00	54.89	4.45	0.25	10	1	255.00	39.00	0
221.1	25	23	20	26	1.26	0.23	0.89	-0.12	0.05	45.00	6.25	0.46	60	1	79.00	12.00	0
222.1	183	165	481	462	0.38	-0.97	0.36	-1.03	0.00	114.80	13.84	0.24	37	1	140.00	32.00	0
207.1	36	44	92	108	0.39	-0.95			0.00	78.68	12.60	0.16	0	1	168.00	6.00	0
111.1	92	30	11	41	8.34	2.12	0.74	-0.30	0.00	46.44	14.06	0.03	0	1	74.00	2.00	0
145.1	3	21	29	38	0.10	-2.26	0.56	-0.58	0.00	13.22	15.64	4.50	0	1	106.00	2.00	1
146.2	0	8	3	11	0.00		0.74	-0.30	0.00	11.75	13.65	4.68	0	1	90.00	2.00	1
203.1	40	66		102			0.65	-0.43	0.50	3.79	6.62	3.14	208	0	23.00	3.00	0
223.1	29	28	99	95			0.30	-1.21	0.00	55.36	5.11	0.14	5	1	103.00	16.00	0
113.1	85	65	210	202	0.41	-0.90	0.32	-1.13	0.00	74.88	13.07	0.09	0	1	208.00	4.00	0
114.1	16	28	72	80	0.23	-1.48	0.35	-1.05	0.00	26.75	10.37	0.38	0	1	5.00	3.00	0
115.1	54	48	66	77	0.82	-0.20	0.62	-0.48	0.00	31.19	11.34	0.31	24	1	9.00	3.00	0
120.1	16	23	126	147	0.13	-2.04	0.16	-1.86	0.00	58.98	27.41	1.04	14	1	104.00	21.00	0
122.1	6	28	33	45	0.18	-1.73	0.62	-0.48	0.00	88.57	13.54	0.38	0	1	92.00	26.00	0
142.1	3	4	17	22	0.18	-1.70	0.18	-1.71	0.00	10.16	12.78	4.78	0	1	47.00	2.00	1
144.2	14	32	351	140	0.04	-3.19	0.23	-1.47	0.00	2.23	10.87	4.58	0	1	21.00	2.00	0
215.1	23	22	32	42	0.71	-0.35	0.52	-0.65	0.00	20.48	11.72	0.54	0	1	56.00	3.00	0
220.2	78	19	194	67	0.40	-0.90	0.28	-1.27	0.00	54.89	4.45	0.25	0	1	255.00	39.00	0
222.2	53	21	182	63	0.29	-1.24	0.33	-1.10	0.00	114.80	13.84	0.24	37	1	140.00	32.00	0
201.2	29	0	129	45	0.23	-1.49			0.00	136.40	18.49	0.43	0	1	143.00	59.00	0
143.1	1	4	10	13	0.13	-2.04	0.30	-1.20	0.00	12.19	13.57	4.66	0	1	88.00	2.00	1
146.1	0	1	13	17	0.00		0.08	-2.52	0.00	11.75	13.65	4.68	0	1	90.00	2.00	1
208.1		770	498	1856			0.41	-0.88	0.00	22.59	8.45	9.23	0	1	18.00	2.00	0

Data sources:

(1) EPA MXD Study: "Trip Generation Tool for Mixed-Use Developments." http://www.epa.gov/smartgrowth/mxd_tripgeneration.html

(2) SANDAG MXD Study: "Trip Generation for Smart Growth: Planning Tools for the San Diego Region" SANDAG, June 2010. http://www.sandag.org/tripgeneration

(3) Caltrans Infill Study: "Trip-Generation Rates for Urban Infill Land Uses in California Phase 2: Data Collection FINAL REPORT." June 2009. http://www.dot.ca.gov/research/researchreports/reports/2009/final_summary_report-calif._infill_trip-generation_rates_study_july_2009.pdf

(4) TCRP Report 128: "Effects of TOD on Housing, Parking, and Travel" 2008. http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_128.pdf

(5) Fehr & Peers: Multi- or mixed-use sites for which Fehr & Peers collected cordon count data (via pneumatic tubes).

(6) UCD Data Collection involved door counts and intercept surveys. It was conducted in Spring 2012. Details about the data collection methodology are described in previous documents.

APPENDIX B: Variables Used for Smart-Growth Trip Generation Adjustment Models

1. Dependent Variables

Variable	Variable Name	Variable Description	Source
Ln(Actual/ITE AM Vehicle Trips)	Ln (Actual/ITE AM Vehicle Trips)	Natural log of ratio of actual AM peak-hour vehicle trips estimated in the field at each study site (based on surveyed person-trips by mode and vehicle occupancy) and AM peak-hour vehicle trips estimated using ITE Trip Generation Manual (2008) trip rates. The ITE-estimated trips at a smart-growth site could be multiplied by this ratio to estimate actual trips.	Derived (2012)
Ln(Actual/ITE PM Vehicle Trips)	Ln (Actual/ITE PM Vehicle Trips)	Natural log of ratio of actual PM peak-hour vehicle trips estimated in the field at each study site (based on surveyed person-trips by mode and vehicle occupancy) and PM peak-hour vehicle trips estimated using ITE Trip Generation Manual (2008) trip rates. The ITE-estimated trips at a smart-growth site could be multiplied by this ratio to estimate actual trips.	Derived (2012)

2. Explanatory Variables

Variable	Variable Name	Variable Description	Source
ResDum	Mid- to High-Density Residential Use	Mid- to High-Density Residential Use indicator variable (1 = Yes, 0 = No).	Derived (2012)
OffDum	Office Use	Office Use indicator variable (1 = Yes, 0 = No).	Derived (2012)
RetDum	Commercial Retail Goods Use	Commercial Retail Goods Use indicator variable (1 = Yes, 0 = No).	Derived (2012)
CofDum	Coffee/Donut Shop Use	Coffee/Donut Shop Use indicator variable (1 = Yes, 0 = No).	Derived (2012)
OthDum	Other Specific Use	Other Specific Use indicator variable (1 = Yes, 0 = No).	Derived (2012)
MXDDum	Multi-Use Site	Multi-Use Site indicator variable (1 = Yes, 0 = No).	Derived (2012)
PctSrfcPkg	Percent site area covered by surface parking	Percentage of site surface area covered by surface parking. Parking on top of a building or in parking structures is not counted as surface parking. Estimated to closest 10%.	Google Earth (2012)
Jobs10H	Jobs within 0.5 miles	Number of jobs within a 0.5-mile, straight-line radius of the center of the study site.	US Census (2010)
Jobs10HX	Jobs within 0.5 miles (000s)	Number of jobs within a 0.5-mile, straight-line radius of the center of the study site. (000s)	US Census (2010)
Pop10H	Population within 0.5 miles	Number of residents within a 0.5-mile, straight-line radius of the center of the study site.	US Census (2010)

Variable	Variable Name	Variable Description	Source
Pop10HX	Population within 0.5 miles (000s)	Number of residents within a 0.5-mile, straight-line radius of the center of the study site. (000s)	US Census (2010)
White10H	White population within 0.5 miles	Total residents within a 0.5-mile, straight-line radius of the center of the study site who are White.	US Census (2010)
PctWhite	Percent White within 0.5 miles	Percent of residents within a 0.5-mile, straight-line radius of the center of the study site who are White.	US Census (2010)
Male10H	Male population within 0.5 miles	Total residents within a 0.5-mile, straight-line radius of the center of the study site who are male.	US Census (2010)
PctMale	Percent male within 0.5 miles	Percentage of total residents within a 0.5-mile, straight-line radius of the center of the study site who are male.	US Census (2010)
Female10H	Female population within 0.5 miles	Total residents within a 0.5-mile, straight-line radius of the center of the study site who are female.	US Census (2010)
PctFemale	Percent female within 0.5 miles	Percentage of total residents within a 0.5-mile, straight-line radius of the center of the study site who are female.	US Census (2010)
U5_10H	Population younger than 5 years within 0.5 miles	Total residents within a 0.5-mile, straight-line radius of the center of the study site who are younger than 5 years.	US Census (2010)
5_9_10H	Age 5 to 9 within 0.5 miles	Total residents within a 0.5-mile, straight-line radius of the center of the study site who are age 5 to 9.	US Census (2010)
10_14_10H	Age 10 to 14 within 0.5 miles	Total residents within a 0.5-mile, straight-line radius of the center of the study site who are age 10 to 14.	US Census (2010)
PctU15	Percent younger than 15 years within 0.5 miles	Percentage of total residents within a 0.5-mile, straight-line radius of the center of the study site who are older than 15 years.	US Census (2010)
15_19_10_H	Age 15 to 19 within 0.5 miles	Total residents within a 0.5-mile, straight-line radius of the center of the study site who are age 15 to 19.	US Census (2010)
20_24_10_H	Age 20 to 24 within 0.5 miles	Total residents within a 0.5-mile, straight-line radius of the center of the study site who are age 20 to 24.	US Census (2010)
25_34_10_H	Age 25 to 34 within 0.5 miles	Total residents within a 0.5-mile, straight-line radius of the center of the study site who are age 25 to 34.	US Census (2010)
35_44_10H	Age 35 to 44 within 0.5 miles	Total residents within a 0.5-mile, straight-line radius of the center of the study site who are age 35 to 44.	US Census (2010)
45_54_10H	Age 45 to 54 within 0.5 miles	Total residents within a 0.5-mile, straight-line radius of the center of the study site who are age 45 to 54.	US Census (2010)
55_64_10H	Age 55 to 64 within 0.5 miles	Total residents within a 0.5-mile, straight-line radius of the center of the study site who are age 55 to 64.	US Census (2010)
65_74_10H	Age 65 to 74 within 0.5 miles	Total residents within a 0.5-mile, straight-line radius of the center of the study site who are age 65 to 74.	US Census (2010)

Variable	Variable Name	Variable Description	Source
75_84_10H	Age 75 to 84 within 0.5 miles	Total residents within a 0.5-mile, straight-line radius of the center of the study site who are age 75 to 84.	US Census (2010)
O84_10H	Population older than 84 years within 0.5 miles	Total residents within a 0.5-mile, straight-line radius of the center of the study site who are older than 84 years.	US Census (2010)
PctO64	Percent older than 64 years within 0.5 miles	Percentage of total residents within a 0.5-mile, straight-line radius of the center of the study site who are older than 64 years.	US Census (2010)
HH_10H	Households within 0.5 miles	Number of households within a 0.5-mile, straight-line radius of the center of the study site.	US Census (2010)
0Veh_10	Households with no vehicles within Census Tract	Number of households with no vehicles within census tract(s) containing the study site. Data were averaged for sites on the border of more than one tract.	US Census (2010)
Pct0Veh	Percent no vehicles within Census Tract	Percent of households with no vehicles within census tract(s) containing the study site. Data were averaged for sites on the border of more than one tract.	US Census (2010)
HU_10H	Housing units within 0.5 miles	Number of housing units within a 0.5-mile, straight-line radius of the center of the study site.	US Census (2010)
VacHU_10H	Vacant housing units within 0.5 miles	Number of vacant housing units within a 0.5-mile, straight-line radius of the center of the study site.	US Census (2010)
PctVacant	Percent vacant housing units within 0.5 miles	Percent of vacant housing units within a 0.5-mile, straight-line radius of the center of the study site.	US Census (2010)
OwnHU_10H	Owner-occupied housing units within 0.5 miles	Number of owner-occupied housing units within a 0.5-mile, straight-line radius of the center of the study site.	US Census (2010)
PctOwner	Percent owner-occupied housing units within 0.5 miles	Percent of owner-occupied housing units within a 0.5-mile, straight-line radius of the center of the study site.	US Census (2010)
RentHU_10H	Renter-occupied housing units within 0.5 miles	Number of renter-occupied housing units within a 0.5-mile, straight-line radius of the center of the study site.	US Census (2010)
PctRental	Percent renter-occupied housing units within 0.5 miles	Percent of renter-occupied housing units within a 0.5-mile, straight-line radius of the center of the study site.	US Census (2010)
InCBD	Within CBD	Study site is within a Los Angeles, Oakland, Sacramento, San Diego, or San Francisco CBD census tract (adjustments were made in San Francisco to reflect growth south of Market Street). Los Angeles, Oakland, Sacramento, San Diego, and San Francisco CBD census tracts were identified in the 1982 Census of Retail Trade.	US Census (2010)

Variable	Variable Name	Variable Description	Source
CBDMi	Distance to center of CBD	Straight-line distance from center of study site to center of the Los Angeles, Oakland, Sacramento, San Diego, or San Francisco CBD (miles). Los Angeles, Oakland, Sacramento, San Diego, and San Francisco CBD census tracts were identified in the 1982 Census of Retail Trade.	US Census (2010)
ComProp_Q	Commercial retail and service properties within 0.25 miles	Number of commercial retail and service properties within a 0.25-mile, straight-line radius of the center of the study site. Distances are measured along the street network, as given in Walkscore.com. Commercial properties include all ITE retail (800-series) and service (900-series) land uses as well as movie theaters and bowling alleys (land use codes 437-445) and post offices (land use code 732). Walkscore.com displays business listings from Google.com and Localeze.com and also allows users to edit and update business locations, so it is one of the most up-to-date sources of commercial retail and service property data.	Walkscore.com (2012)
ComDiv_Q	Commercial retail diversity within 0.25 miles	Total number of different categories of commercial retail properties within a 0.25-mile, straight-line radius of the center of the study site. Possible categories include Post offices, Bike shops, Restaurants, Coffee, Groceries, Shopping, Books, Bars, Entertainment, and Banking (not ATMs), so the maximum value for this variable is 10. Categories are defined by Walkscore.com.	Walkscore.com (2012)
Inters_Q	Number of intersections within 0.25 miles	Total number of roadway intersections within a 0.25-mile, straight-line radius of the center of the study site. This includes intersections with 3 or more public roadway legs. Driveway intersections with public roadways are not included. Interchanges are not included.	US Census TIGER roadway centerline GIS files (2010)
3LegInt_Q	Number of 3-leg intersections within 0.25 miles	Total number of 3-leg roadway intersections within a 0.25-mile, straight-line radius of the center of the study site. This includes intersections with exactly 3 public roadway legs. Driveway intersections with public roadways are not included. Interchanges are not included.	US Census TIGER roadway centerline GIS files (2010)
4OrMreLgInt_Q	Number of 4-or-more-leg intersections within 0.25 miles	Total number of 4-or-more-leg roadway intersections within a 0.25-mile, straight-line radius of the center of the study site. This includes intersections with 4 or more public roadway legs. Driveway intersections with public roadways are not included. Interchanges are not included.	US Census TIGER roadway centerline GIS files (2010)

Variable	Variable Name	Variable Description	Source
FwyRmp_Q	Freeway ramp within 0.25 miles	Freeway ramp is present within a 0.25-mile, straight-line radius of the center of the study site (1 = Yes, 0 = No).	Google Earth (2012)
MaxLanes	Maximum adjacent roadway lanes	Maximum number of travel lanes at an intersection location along any roadway adjacent to the development site. Turning lanes are included but bicycle lanes are not.	Google Earth (2012)
AvgSetback	Average distance to sidewalk	Average straight-line distance to the sidewalk from all major building entrances (feet). Major entrances include the main pedestrian entrance and automobile garage entrances.	Google Earth (2012)
PkgMeters	Metered parking within 0.1 miles	Metered parking is present within a 0.1-mile, straight-line radius of the center of the study site (1 = Yes, 0 = No). Metered parking only includes metered on-street parking. Metered off-street surface lots or parking structures are not included.	Google Street View (2012)
PkgStrctr	Structured parking within 0.1 miles	Structured parking is present within a 0.1-mile, straight-line radius of the center of the study site (1 = Yes, 0 = No).	Google Steet View (2012)
PctSW_Q	Percent sidewalk coverage within 0.25 miles	Percent sidewalk coverage within a 0.25-mile, straight-line radius of the center of the study site. Estimated to closest 10%. Sidewalks on both sides of the roadway are considered to be 100% coverage. Sidewalk on one side of the roadway is considered to be 50% coverage. Sidewalks on both sides of half of a roadway segment is considered to be 50% coverage.	Google Earth (2012)
BikeFac_2B	Bicycle facilities within 2 blocks	Bicycle facilities are present within 2 blocks of the boundary of the study site (1 = Yes, 0 = No). Bicycle facilities include multi-use trails, bicycle lanes, and other on-road facilities dedicated for bicycle use. Shared-lane markings and signed bicycle routes are not included.	Google Earth (2012)
PctBkFac_H	Percent of arterial/collector roadways with bicycle facilities within 0.5 miles	Percent of arterial/collector roadway centerline miles with bicycle facilities on at least one side of the roadway within a 0.5-mile, straight-line radius of the center of the study site. Bicycle facilities include shared-use paths or cycle tracks adjacent to the roadway, bicycle lanes, and other on-road facilities dedicated for bicycle use. Shared-lane markings and signed bicycle routes are not included.	Google Earth (2012)
Trail_H	Prescence of multi-use trail within 0.5 miles	A multi-use trail is present within a 0.5-mile, straight-line radius of the center of the study site (1 = Yes, 0 = No). Multi-use trail must be a minimum of 10-feet wide to be counted.	Google Earth (2012)

Variable	Variable Name	Variable Description	Source
BusLines_Q	Number of bus line stop locations within 0.25 miles	Number of individual bus stop locations on all bus lines that pass within any part of a 0.25-mile, straight-line radius around the study site during a typical weekday PM peak hour (4:30 p.m. to 5:30 p.m. was considered to be the peak hour for this measurement). Bus lines are considered individually (e.g., if 2 routes use the same stop, the stop is counted 2 times). Note that bus stop locations are only counted if they are within the 0.25-mile, straight-line radius.	Transit agency bus schedules (2012)
RailLines_H	Number of train line stop locations within 0.5 miles	Number of individual rail stop locations on all rail lines that pass within any part of a 0.5-mile, straight-line radius around the study site during a typical weekday PM peak hour (4:30 p.m. to 5:30 p.m. was considered to be the peak hour for this measurement). Rail lines are considered individually (e.g., if 2 routes use the same stop, the stop is counted 2 times). Note that rail stop locations are only counted if they are within the 0.5-mile, straight-line radius.	Transit agency train schedules (2012)
RailLines_Q	Number of train line stop locations within 0.25 miles	Number of individual rail stop locations on all rail lines that pass within any part of a 0.25-mile, straight-line radius around the study site during a typical weekday PM peak hour (4:30 p.m. to 5:30 p.m. was considered to be the peak hour for this measurement). Rail lines are considered individually (e.g., if 2 routes use the same stop, the stop is counted 2 times). Note that rail stop locations are only counted if they are within the 0.25-mile, straight-line radius.	Transit agency train schedules (2012)
TransitLines_Q	Number of bus or train line stop locations within 0.25 miles	Number of individual rail or bus stop locations on all rail or bus lines that pass within any part of a 0.25-mile, straight-line radius around the study site during a typical weekday PM peak hour (4:30 p.m. to 5:30 p.m. was considered to be the peak hour for this measurement). Rail or bus lines are considered individually (e.g., if 2 routes use the same stop, the stop is counted 2 times). Note that rail or bus stop locations are only counted if they are within the 0.25-mile, straight-line radius.	Transit agency bus and train schedules (2012)
Rail_Ft	Distance to rail station	Straight-line distance from center of study site to nearest rail station (feet). Rail includes heavy rail, metro rail, and light rail.	Google Earth (2012)
Rail_H	Rail transit within 0.5 miles	Rail transit station is present within a 0.5-mile, straight-line distance of the center of the study site (1 = Yes, 0 = No). Rail transit includes heavy rail, metro rail, and light rail.	Google Earth (2012)
University	Site is within 1.0 miles of a major university	Site is within 1.0 miles (straight-line distance) of a major college or university (full-time enrollment >5,000 students) (1 = Yes, 0 = No).	Google Earth (2012)

Variable	Variable Name	Variable Description	Source
SoCal	Site is in Southern California	Site is in the Los Angeles or San Diego region (1 = Yes, 0 = No).	Google Earth (2012)
Post offices	Post offices within 0.25 miles	Number of post offices within a 0.25-mile, straight-line radius around the center of the study site. Distances are measured along the street network, as given in Walkscore.com. Walkscore.com displays business listings from Google.com and Localeze.com and also allows users to edit and update business locations, so it is one of the most up-to-date sources of commercial retail and service property data.	Walkscore.com (2012)
Bike shops	Bike shops within 0.25 miles	Number of bike shops within a 0.25-mile, straight-line radius around the center of the study site. Distances are measured along the street network, as given in Walkscore.com. Walkscore.com displays business listings from Google.com and Localeze.com and also allows users to edit and update business locations, so it is one of the most up-to-date sources of commercial retail and service property data.	Walkscore.com (2012)
Restaurants	Restaurants within 0.25 miles	Number of restaurants within a 0.25-mile, straight-line radius around the center of the study site. Distances are measured along the street network, as given in Walkscore.com. Walkscore.com displays business listings from Google.com and Localeze.com and also allows users to edit and update business locations, so it is one of the most up-to-date sources of commercial retail and service property data.	Walkscore.com (2012)
Coffee	Coffee shops within 0.25 miles	Number of coffee shops within a 0.25-mile, straight-line radius around the center of the study site. Distances are measured along the street network, as given in Walkscore.com. Walkscore.com displays business listings from Google.com and Localeze.com and also allows users to edit and update business locations, so it is one of the most up-to-date sources of commercial retail and service property data.	Walkscore.com (2012)
Groceries	Grocery stores within 0.25 miles	Number of grocery stores within a 0.25-mile, straight-line radius around the center of the study site. Distances are measured along the street network, as given in Walkscore.com. Walkscore.com displays business listings from Google.com and Localeze.com and also allows users to edit and update business locations, so it is one of the most up-to-date sources of commercial retail and service property data.	Walkscore.com (2012)

Variable	Variable Name	Variable Description	Source
Shopping	Retail stores within 0.25 miles	Number of retail stores within a 0.25-mile, straight-line radius around the center of the study site. Distances are measured along the street network, as given in Walkscore.com. Walkscore.com displays business listings from Google.com and Localeze.com and also allows users to edit and update business locations, so it is one of the most up-to-date sources of commercial retail and service property data.	Walkscore.com (2012)
Book stores	Book stores within 0.25 miles	Number of book stores within a 0.25-mile, straight-line radius around the center of the study site. Distances are measured along the street network, as given in Walkscore.com. Walkscore.com displays business listings from Google.com and Localeze.com and also allows users to edit and update business locations, so it is one of the most up-to-date sources of commercial retail and service property data.	Walkscore.com (2012)
Bars	Bars within 0.25 miles	Number of bars within a 0.25-mile, straight-line radius around the center of the study site. Distances are measured along the street network, as given in Walkscore.com. Walkscore.com displays business listings from Google.com and Localeze.com and also allows users to edit and update business locations, so it is one of the most up-to-date sources of commercial retail and service property data.	Walkscore.com (2012)
Entertainment	Entertainment uses within 0.25 miles	Number of entertainment uses within a 0.25-mile, straight-line radius around the center of the study site. Distances are measured along the street network, as given in Walkscore.com. Walkscore.com displays business listings from Google.com and Localeze.com and also allows users to edit and update business locations, so it is one of the most up-to-date sources of commercial retail and service property data.	Walkscore.com (2012)
Banks (not ATMs)	Banks within 0.25 miles	Number of banks within a 0.25-mile, straight-line radius around the center of the study site. Distances are measured along the street network, as given in Walkscore.com. Walkscore.com displays business listings from Google.com and Localeze.com and also allows users to edit and update business locations, so it is one of the most up-to-date sources of commercial retail and service property data.	Walkscore.com (2012)

3. Data Set Selection Variables

Variable	Variable Name	Variable Description	Source
AM_Analysis	AM Analysis Set	Site is one of 46 sites included in the main analysis database for AM peak hour trips (1 = yes, 0 = no). Sites were not included if no field data were collected or reported, fewer than 10 trips were reported during the peak hour, the trip mode split was based on fewer than 30 surveys at a Spring 2012 site, the site had trips at non-standard hours for a particular land use (clothing store with many trips during the AM period), or there were 0 vehicle trips reported (so it was not possible to take the natural log).	Derived (2012)
AM_Validation	AM Validation Set	Site is one of 11 sites included in the validation database for AM peak hour trips (1 = yes, 0 = no). Sites were not included if no field data were collected or reported, fewer than 10 trips were reported during the peak hour, the trip mode split was based on fewer than 30 surveys at a Spring 2012 site, the site had trips at non-standard hours for a particular land use (clothing store with many trips during the AM period), or there were 0 vehicle trips reported (so it was not possible to take the natural log).	Derived (2012)
PM_Analysis	PM Analysis Set	Site is one of 50 sites included in the main analysis database for PM peak hour trips (1 = yes, 0 = no). Sites were not included if no field data were collected or reported, fewer than 10 trips were reported during the peak hour, the trip mode split was based on fewer than 30 surveys at a Spring 2012 site, the site had trips at non-standard hours for a particular land use (clothing store with many trips during the AM period), or there were 0 vehicle trips reported (so it was not possible to take the natural log).	Derived (2012)

Variable	Variable Name	Variable Description	Source
PM_Validation	PM Validation Set	Site is one of the 13 sites included in the validation database for PM peak hour trips (1 = yes, 0 = no). Sites were not included if no field data were collected or reported, fewer than 10 trips were reported during the peak hour, the trip mode split was based on fewer than 30 surveys at a Spring 2012 site, the site had trips at non-standard hours for a particular land use (clothing store with many trips during the AM period), or there were 0 vehicle trips reported (so it was not possible to take the natural log).	Derived (2012)

APPENDIX C: Explanatory Variable Descriptive Statistics (PM Analysis Dataset)

Variable	Variable Name	N	Minimum	Maximum	Mean	Std. Dev.
ResDum	Mid- to High-Density Residential Use	50	0.00	1.00	0.40	0.49
OffDum	Office Use	50	0.00	1.00	0.24	0.43
RetDum	Commercial Retail Goods Use	50	0.00	1.00	0.06	0.24
CofDum	Coffee/Donut Shop Use	50	0.00	1.00	0.06	0.24
OthDum	Other Specific Use	50	0.00	1.00	0.02	0.14
MXDDum	Multi-Use Site	50	0.00	1.00	0.22	0.42
PctSrfcPkg	Percent site area covered by surface parking	50	0.00	0.50	0.06	0.12
Jobs10H	Jobs within 0.5 miles	50	487.06	136400.00	24350.72	29899.19
Jobs10HX	Jobs within 0.5 miles (000s)	50	0.49	136.40	24.35	29.90
Pop10H	Population within 0.5 miles	50	787.35	42108.72	9718.17	6810.69
Pop10HX	Population within 0.5 miles (000s)	50	0.79	42.11	9.72	6.81
White10H	White population within 0.5 miles	50	533.88	22470.56	4815.98	3591.04
PctWhite	Percent White within 0.5 miles	50	0.21	0.82	0.52	0.17
Male10H	Male population within 0.5 miles	50	426.67	21949.35	5090.07	3707.70
PctMale	Percent male within 0.5 miles	50	0.46	0.66	0.52	0.05
Female10H	Female population within 0.5 miles	50	360.69	20159.37	4628.10	3184.02
PctFemale	Percent female within 0.5 miles	50	0.34	0.54	0.48	0.05
U5_10H	Population younger than 5 years within 0.5 miles	50	34.26	941.33	349.66	206.44
5_9_10H	Age 5 to 9 within 0.5 miles	50	11.99	683.12	240.56	158.69
10_14_10H	Age 10 to 14 within 0.5 miles	50	12.93	650.39	209.20	147.31
PctU15	Percent younger than 15 years within 0.5 miles	50	0.03	0.26	0.09	0.05
15_19_10_H	Age 15 to 19 within 0.5 miles	50	20.60	2968.92	420.54	590.52
20_24_10_H	Age 20 to 24 within 0.5 miles	50	61.39	5838.19	1094.83	1332.93
25_34_10_H	Age 25 to 34 within 0.5 miles	50	144.74	10988.41	2417.88	1738.50
35_44_10H	Age 35 to 44 within 0.5 miles	50	144.34	6317.39	1486.63	1063.27
45_54_10H	Age 45 to 54 within 0.5 miles	50	77.63	5116.45	1194.04	913.12
55_64_10H	Age 55 to 64 within 0.5 miles	50	52.82	4869.44	1036.93	849.20
65_74_10H	Age 65 to 74 within 0.5 miles	50	16.83	3093.84	600.06	538.70
75_84_10H	Age 75 to 84 within 0.5 miles	50	14.48	2656.32	445.59	487.97

Variable	Variable Name	N	Minimum	Maximum	Mean	Std. Dev.
O84_10H	Population older than 84 years within 0.5 miles	50	5.41	1583.07	222.26	266.65
PctO64	Percent older than 64 years within 0.5 miles	50	0.04	0.24	0.12	0.05
HH_10H	Households within 0.5 miles	50	467.19	25228.52	5067.88	3965.19
0Veh_10	Households with no vehicles within Census Tract	50	0.00	1529.00	442.64	418.48
Pct0Veh	Percent no vehicles within Census Tract	50	0.00	0.82	0.22	0.20
HU_10H	Housing units within 0.5 miles	50	618.28	27795.41	5677.46	4428.75
VacHU_10H	Vacant housing units within 0.5 miles	50	52.01	2566.89	609.58	534.35
PctVacant	Percent vacant housing units within 0.5 miles	50	0.04	0.34	0.11	0.06
OwnHU_10H	Owner-occupied housing units within 0.5 miles	50	35.13	3162.80	1016.43	634.29
PctOwner	Percent owner-occupied housing units within 0.5 miles	50	0.05	0.58	0.22	0.13
RentHU_10H	Renter-occupied housing units within 0.5 miles	50	251.99	22065.72	4051.45	3574.53
PctRental	Percent renter-occupied housing units within 0.5 miles	50	0.36	0.85	0.67	0.12
InCBD	Within CBD	50	0.00	1.00	0.16	0.37
CBDMi	Distance to center of CBD	50	0.03	40.10	7.75	9.49
ComProp_Q	Commercial retail and service properties within 0.25 miles	50	0.00	107.00	42.32	30.38
ComDiv_Q	Commercial retail diversity within 0.25 miles	50	0.00	10.00	7.02	2.56
Inters_Q	Number of intersections within 0.25 miles	50	3.00	85.00	40.12	16.48
3LegInt_Q	Number of 3-leg intersections within 0.25 miles	50	1.00	63.00	19.80	11.02
4OrMreLgInt_Q	Number of 4-or-more-leg intersections within 0.25 miles	50	2.00	52.00	20.32	12.48
FwyRmp_Q	Freeway ramp within 0.25 miles	50	0.00	1.00	0.30	0.46
MaxLanes	Maximum adjacent roadway lanes	50	2.00	12.00	5.54	2.10
AvgSetback	Average distance to sidewalk	50	0.00	524.00	76.02	115.64
PkgMeters	Metered parking within 0.1 miles	50	0.00	1.00	0.62	0.49
PkgStrctr	Structured parking within 0.1 miles	50	0.00	1.00	0.86	0.35
PctSW_Q	Percent sidewalk coverage within 0.25 miles	50	0.45	1.00	0.94	0.13
BikeFac_2B	Bicycle facilities within 2 blocks	50	0.00	1.00	0.80	0.40
PctBkFac_H	Percent of arterial/collector roadways with bicycle facilities within 0.5 miles	50	0.00	0.85	0.31	0.24
Trail_H	Prescence of multi-use trail within 0.5 miles	50	0.00	1.00	0.64	0.48
BusLines_Q	Number of bus line stop locations within 0.25 miles	50	0.00	255.00	43.42	50.84
RailLines_H	Number of train line stop locations within 0.5 miles	50	0.00	59.00	6.82	12.14

Variable	Variable Name	N	Minimum	Maximum	Mean	Std. Dev.
RailLines_Q	Number of train line stop locations within 0.25 miles	50	0.00	17.00	2.50	4.41
TransitLines_Q	Number of bus or train line stop locations within 0.25 miles	50	3.00	264.00	45.90	52.50
Rail_Ft	Distance to rail station	50	100.00	50000.00	7837.80	16044.40
Rail_H	Rail transit within 0.5 miles	50	0.00	1.00	0.76	0.43
University	Site is within 1.0 miles of a major university	50	0.00	1.00	0.08	0.27
SoCal	Site is in Southern California	50	0.00	1.00	0.40	0.49
Post offices	Post offices within 0.25 miles	50	0.00	4.00	0.92	1.12
Bike shops	Bike shops within 0.25 miles	50	0.00	3.00	0.60	0.93
Restaurants	Restaurants within 0.25 miles	50	0.00	30.00	12.90	7.62
Coffee	Coffee shops within 0.25 miles	50	0.00	15.00	6.22	4.36
Groceries	Grocery stores within 0.25 miles	50	0.00	12.00	2.76	2.48
Shopping	Retail stores within 0.25 miles	50	0.00	40.00	9.90	10.28
Book stores	Book stores within 0.25 miles	50	0.00	5.00	1.16	1.40
Bars	Bars within 0.25 miles	50	0.00	14.00	2.38	3.21
Entertainment	Entertainment uses within 0.25 miles	50	0.00	10.00	1.52	2.12
Banks (not ATMs)	Banks within 0.25 miles	50	0.00	20.00	3.96	4.77