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Final Report:
California Smart-Growth Trip Generation Rates Study

March 2013

Susan L. Handy
Kevan R. Shafizadeh
Robert Schneider

Institute of Transportation Studies ◦ University of California, Davis
1605 Tilia Street ◦ Davis, California 95616
PHONE (530) 752-6548 ◦ FAX (530) 752-6572
its.ucdavis.edu

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16. ABSTRACT

The Institute of Transportation Engineers'(ITE), Trip Generation Manual provides estimates of the number of trips per unit size that a new development is likely to generate. Most of the data on which ITE bases its trip-generation rates is obtained at suburban locations. As a result, these rates may not accurately reflect the trip generation patterns at smart growth sites where close proximity to other destinations as well as transit and bike facilities make non-vehicular forms of travel more prevalent.

To address this bias, Schneider et al. (2013a) developed a methodology for producing more accurate trip-generation rates for smart growth sites across California. The original study produced a data collection methodology, a smart growth factor incorporating 8 variables representing the degree to which a site reflects smart growth characteristics, trip generation adjustment models for both AM and PM peak hours, and a spreadsheet tool for use by practitioners. The trip-generation models were based on data from more than 50 sites in California. Validation of these models was conducted using data from several sites left out of the estimation process.

Follow-up work was done to test and improve the PM model developed in the original study. The follow-up work supplements the original trip generation data collected in California with data collected at 78 sites in the Portland region by Kelly Clifton and others (2012) at Portland State University. These new sites were located across the Portland area in both smart growth and non-smart growth developments. The following sections describe the work done to verify the original model, re-estimate a new PM model based on the combined dataset, and conduct validati

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AUTHORS
Susan Handy, Ph.D., University of California, Davis
Kevan Shafizadeh, Ph.D., California State University, Sacramento
Robert Schneider, Ph.D., University of California, Davis

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Final Report for the California Smart-Growth Trip Generation Rates Study

1. Introduction

The California Environmental Quality Act (CEQA) and other state, federal, and local laws require the identification, analysis, and mitigation of transportation-related impacts of proposed land use projects. The first step in preparing a transportation impact analysis is to estimate the number of trips by cars, trucks, and other modes of travel that may result from a proposed land use project – a process commonly referred to as "trip-generation." Currently, practitioners typically use trip-generation rates published by the Institute of Transportation Engineers (ITE), a national professional organization.

For the most part, ITE's trip-generation rates are based on data obtained at suburban locations that lack good transit or bicycle and pedestrian facilities. Not surprisingly, studies indicate that these rates often significantly over-estimate the number of trips from cars and trucks for land use projects located in urban areas near transit and within easy walking distance of other land uses (Tindale Oliver and Associates 1993; Steiner 1998; Muldoon and Bloomberg 2008; Arrington and Cervero 2008; Kimley Horn Associates 2009; Bochner *et al*. 2011). In fact, ITE guidelines state that their trip-generation rates data should not be used for such projects, here labeled "smart growth" projects.

However, there is currently no commonly accepted methodology in the U.S. for estimating multi-modal trip-generation rates associated with smart-growth projects. This makes it very difficult for practitioners to accurately estimate the traffic impacts of such projects, or to identify and recommend appropriate or adequate transportation "mitigations," including walking, biking, and transit facilities. By following existing guidelines, transportation engineers often over-prescribe automobile infrastructure in smart-growth locations, resulting in wider roadways, more turning lanes, and more parking spaces than necessary. In addition, there is no established approach to recommend adequate pedestrian, bicycle, or public transit facilities that may improve conditions for traveling by these other modes.

The goal of this project was to develop a methodology and spreadsheet tool that practitioners can use to estimate multi-modal trip-generation rates for proposed smart-growth land use development projects in California. The project involved multiple tasks (Table 1), carried out between September 2009 and February 2013. The UC Davis Project Team (Table 2) collected trip-generation data at 30 smart growth sites in California and used this information, along with trip generation data from other studies, to develop a method built into a spreadsheet tool that adjusts trip-generation estimated based on ITE rates. The technical advisory panel for the project, called the "Practitioners Panel," provided important input throughout the project. The Panel comprised representatives from state, regional, and local agencies as well as private consulting firms and non-governmental organizations (Table 3).

This report describes three key steps in the process of developing the tool: the identification and evaluation of existing tools, the development and implementation of a data collection methodology, and the development of the trip generation method. Appendices A-F present the detailed results of the project (Table 4). This report and the appendices are available at: http://ultrans.its.ucdavis.edu/projects/smart-growth-trip-generation.

Table 1. Project Tasks

Task	Description	Appendix
1	Operating procedures and acceptance criteria	-
2	Definitions: define key terms required for this effort	A
3	Identification, review, summary and evaluation of available information	B
4	Practitioners Panel	-
5	Design door count procedures	E
6	Evaluate existing analysis methodologies	C, D
7	Select or modify existing methodology, or develop a new methodology	F
8	Draft and Final Summary Reports of the Entire Study	-
9	Design Data Collection Procedures and Intercept Survey	E
10	Site selection	E
11	Pilot count and summary	E
12	Cordon count collection and summary	E
13	Cordon count analysis and report	E

Table 2. Project Team

Terry Parker, M.A., Caltrans Project Manager Dr. Susan Handy, Principal Investigator Dr. Kevan Shafizadeh Dr. Robert Schneider Dr. Richard K. Lee Dr. Deborah Niemeier Dr. Brian Bochner, Texas Transportation Institute Dr. Benjamin Sperry, Texas Transportation Institute	Rachel Maiss, graduate student Josh Miller, graduate student David van Herick, graduate student Nanako Tenjin, graduate student Calvin Thigpen, graduate student Mary Madison Campbell, project assistant

Table 3. Practitioner Panel Members

Organization	**Representative**
State & Regional Agencies	
Caltrans – (Calif. Dept. of Transportation)	Marc Birnbaum, Supervising Senior Transportation Planner (HQ Traffic Operations Division)
Metropolitan Planning Organization	
San Diego Association of Governments (SANDAG)	Christine Eary, Associate Regional Planner

Local Government	
City of San Diego – Planning Department	Samir Hajjiri, Senior Traffic Engineer (PE)
Non-profit organizations	
TransForm (SF Bay Area)	Ann Cheng, Senior Planner, GreenTRIP manager Jennifer West, GreenTRIP Program Associate
Consultants, etc.	
Economic & Planning Systems (EPS)	Ed Sullivan, GIS Senior Technical Associate
Gibson Transportation Consulting	Pat Gibson, President (PTOE)
Pang Ho PHA Associates	Pang Ho, Principal, PH Associates (PE)
Parsons Brinckerhoff (PB)	Donald Hubbard, Senior Supervising Planner
Townworks + DPZ	Paul Crabtree, Principal (PE)
TPG Inc.	Charles Clouse, Principal (AICP, PCP)
VRPA Technologies, Inc.	Erik Ruehr, Director of Traffic Engineering (PE)

Table 4. Appendices to the Final Report

Appendix A. Definition of "smart growth" Appendix B. Annotated review of land use & transportation literature Appendix C. Summary & comparison of existing tools worldwide Appendix D. Evaluation of the operation & accuracy of available methodologies Appendix E. UCD's Data Collection Methodology and Results Appendix F. Method for Adjusting ITE Trip Generation Estimates for Smart Growth Projects Smart Growth Trip-Generation Adjustment Tool

2. Existing Tools

The UC Davis Project Team searched for existing tools that provide trip generation estimates for smart growth projects (as described in Appendices C and D). A key consideration was the tool's ability to respond to location, density, mixed land uses, and other design characteristics that have been found to facilitate non-motorized travel and thereby reduce vehicle trips. In general, the search emphasized tools that are more context-sensitive than the traditional ITE *Trip Generation* method.

The Team identified eight existing tools. A majority of the identified tools adjust the ITE trip generation rates (or an alternative set of rates compiled by the San Diego Association of Governments (SANDAG)) to better reflect the effects of location, density, mixed land uses, and other design characteristics on trip generation. In addition to this type of tool, the team identified two other types: tools that provide rates based on trip generation data collected at sites with smart growth characteristics, and one tool that uses person-trip data from a travel survey. All of these tools showed the potential to be better than the traditional ITE *Trip Generation* method, though none was without obvious limitations.

Table 5. Existing Tools Identified and Assessed

Tool	Included in Assessment?
Adjustments to ITE/SANDAG Rates	
ITE Mixed-Use	Yes
EPA Mixed-Use Model/SANDAG Mixed-Use Model	Yes
URBEMIS	Yes
NCHRP 8-51 Method and Spreadsheet Tool	Yes
Eakland's Model	No – San Diego only
Organized Empirical Database Tools	
UK's TRICS	No – UK data only
New Zealand Trips and Parking Database	No – NZ data only
Person-Trip Based Tools	
San Francisco Method/MTC Survey Method	Yes

The Team undertook an evaluation of five of these tools. The evaluation consisted of two parts:

1. An assessment of their operational characteristics, based on criteria identified by an expanded Practitioners Panel;
2. An analysis of the accuracy of each tool in estimating trip generation for 22 sites in California for which observed trip counts were available.

Operational Criteria

An expanded Practitioners Panel that included 20 representatives from various local and regional agencies, non-profit groups, and consulting firms identified key operational criteria by which the tools were assessed. During several conference calls, the panelists discussed the qualities – in addition to accuracy – that they most require in a tool for estimating trip generation for smart growth land use projects. From these discussions, the Team compiled a list of operational criteria and reviewed them with the panelists. The operational criteria were grouped into the following categories: 1) Ease of use; 2) Sensitivity to key smart growth elements; 3) Input requirements; 4) Output features; and 5) Usability of a methodology or tool in helping to define smart growth projects based on their performance.

Based on its experience in applying each method (to analyze their accuracy, as described below), the Team rated the methods/tools on each criterion. The Team then invited panelists to rate the criteria as to their relative importance via an on-line survey. Eight members of the Practitioners Panel responded to the on-line survey. Respondents were asked to rate each criterion from one to six with one being "least important" and six being "most important." The eleven top-rated criteria are shown in Table 6. The Team then assessed tools based on the combination of the performance rating and the importance rating. This assessment showed that no one tool met every operational goal, and thus none emerged as a clear "winner."

Table 6. Most Important Operational Criteria

Criterion	**Criterion Type**	**Rating (on 6 point scale)**
Sensitivity of outputs to inputs	Input requirements	6.0
Results replicable by other analysts	Output	5.8
Results should not fluctuate excessively	Additional criteria	5.6
Method measures the performance of different kinds of land use policies	Additional criteria	5.6
AM/PM/daily/other time frames reported	Output	5.4
Auto vs. other trip generation rates	Output	5.3
LU context variables	Sensitivity	5.1
Internal capture shown	Output	5.0
Project-level variables	Sensitivity	5.0
Transport variables	Sensitivity	4.9
Project description by land use(s) and size	Output	4.9

Accuracy

The Practitioners Panel identified the ability to accurately predict trip generation for projects as the most important criterion against which each method or tool should be evaluated. To assess the relative accuracy of each of the five candidate methods, the Team compared available cordon counts at ten multi-use sites and twelve infill sites in California against estimates from the five candidate methodologies (see Appendix D). These methods were also compared to the industry standard ITE trip generation rates for single land uses.

Traffic count data used to evaluate the accuracy of the candidate methodologies come from two sources: 1) daily and peak-hour traffic counts at 10 sites in California originally collected for validation of the EPA/SANDAG mixed-use method (referred to as the "multi-use sites"); and 2) peak hours cordon count and intercept survey data for 12 infill sites that was gathered for Caltrans' *Trip-Generation Rates for Urban Infill Land Uses in California* study (referred to as the "infill sites"). Most of the multi-use sites are medium to large-scale developments (5 to 200+ acres) located outside urban cores. By contrast, the Infill sites are single uses located in urban cores close to high-quality transit. Appendix D provides information about each of the sites.

The results of the accuracy analysis also did not identify a clear "winner." For the multi-use sites, the EPA mixed-use method produced the most accurate estimate for the greatest number of sites, particularly for daily counts. This was not surprising, given that these sites were chosen based on their similarity to the sites used to calibrate the method. For the sites for which the EPA method was not most accurate, no one method proved best: the other four methods were each most accurate for at least two site-time period combinations. For the single-use urban infill sites, a clearly best method did not emerge, with each method proving most accurate for some number of site-time period combinations. However, the results showed that all of the methods performed better than the ITE rates for both multi-use and infill sites.

Given the limitations of the available tools for estimating trip generation at smart growth sites with respect to both operational characteristics and accuracy, the Project Team under the guidance of the Practitioners Panel proceeded to pursue the development of an entirely new method based on the data used in accuracy assessment as well as additional data collected at smart growth sites in California as a part of this project.

3. Data Collection

The UC Davis Project Team, with input from a subcommittee of the Practitioners Panel, next developed a data collection and analysis methodology to document the number of pedestrian, bicycle, public transit, and automobile trips generated by developments in smart-growth areas in California (as described in detail in Appendix E). The methodology builds upon established methods so that it can be integrated easily into standard transportation engineering and planning practice. It can be replicated and refined in other communities seeking to collect trip generation data in smart-growth areas.

The Team applied the methodology in the field at 30 study locations in California during spring 2012. Study locations consisted of a single land use within a smart growth development site; detailed descriptions of the sites and the criteria by which they were selected are provided in Appendix E. Field data collection involved a combination of door counts and intercept surveys. The core component at each study location was a count of all people entering and exiting the site or targeted land use. In-person intercept surveys were administered to a sample of people as they exited doors at each study location. These surveys were designed to determine 1) the mode, time of day, origin, and length of inbound trips to the study location and 2) the mode, time of day, destination, and length of outbound trips from the study location. The intercept surveys also collected information about vehicle occupancy so that the person-trip counts for automobile users could be compared to ITE vehicle-based trip rates.

Overall, the door counters recorded a total of 31,515 individual entries and exits at the 30 locations. The surveyors approached a total of 5,501 people and of these, 3,371 (61%) provided at least a basic response with their current travel mode (2,129 refused to participate and one did not provide a travel mode). The 3,371 respondents reported a total of 5,170 trips. Based on these data, the Team calculated peak-hour person trips by mode for each location and compared peak-hour vehicle trips to estimates of such trips based on ITE rates. The analysis showed that automobile person-trips accounted for fewer than half of morning peak-hour trips at 10 study locations and fewer than half of afternoon peak-hour trips at 11 study locations. As a result, the numbers of vehicle trips at these smart growth sites were, on average, approximately half as high as predicted by standard ITE trip generation rates.

This data collection methodology has several advantages over existing approaches that use automated technologies to count automobiles entering and exiting access points to developments. These advantages are particularly important in urban areas with mixed-use developments, mixed-use buildings, and a variety of parking arrangements. Existing methods that only capture automobile trips would have missed more than half of all person-trips recorded at the study locations: overall, 27% of person-trips were made by walking, 21% by transit, and 3% by bicycle.

4. Trip Generation Method

Although vehicle trips at the 30 California smart growth locations for which UC Davis collected data were, on average, much lower than ITE rates would predict, the difference between actual and ITE-estimated vehicle trips varied from site to site (Table 7). 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. To this end, the UC Davis Project Team developed a method that can be used by practitioners to adjust estimates based on existing ITE rates to produce more accurate weekday AM and PM peak hour vehicle trip generation rate estimates at developments with smart-growth characteristics.

The method takes estimates of vehicle trips based on ITE rates and adjusts them based on characteristics of the proposed development project and its surrounding context (as described in detail in Appendix F). At the core of the method 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 models were developed using a database of vehicle trip counts and site/context data for a sample of 50 "smart-growth" sites in California. This sample was drawn from the 30 locations for which UC Davis collected data in Spring 2012, the 22 sites used in the assessment of existing tools (see Section 2, above), and sites from other studies; sites not used in developing the equations were reserved for validating the equations.

The starting point for the model development process was 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

Table 7. Actual Peak-hour Vehicle-Trips versus Estimated Vehicle-Trips from Published ITE Rates

	Targeted Land Uses (ITE Use Code)[1]				AM Peak Hour								PM Peak Hour							
Site Name	**Mid- to High-Density Residential**	**Office**	**Commercial Retail Goods**	**Coffee/Donut Shop**	Actual Total Person Trips[2]	Actual Auto Person Trips[3]	Actual Auto Occupancy[4]	**Actual Vehicle Trips**	**ITE-Estimated Vehicle Trips[5]**	Actual-ITE Vehicle Trips	ITE/Actual Vehicle Trips[6]	ITE-Estimated Total Person Trips[7]	Actual Total Person Trips[2]	Actual Auto Person Trips[3]	Actual Auto Occupancy[4]	**Actual Vehicle Trips**	**ITE-Estimated Vehicle Trips[5]**	Actual-ITE Vehicle Trips	ITE/Actual Vehicle Trips[6]	ITE-Estimated Total Person Trips[7]
Pegasus	222				136	42	1.18	**36**	**92**	-56	2.56	109								
Sakura Crossing	223				106	85	1.10	**77**	**66**	11	0.86	73	152	68	1.10	**61**	**86**	-25	1.40	95
Argenta	222				89	33	1.34	**25**	**53**	-28	2.14	71	107	29	1.34	**22**	**62**	-40	2.85	83
Fremont Building	223				50	31	1.23	**25**	**20**	5	0.80	25	42	28	1.23	**23**	**26**	-3	1.13	32
Artisan on 2nd	223				62	41	1.28	**32**	**34**	-2	1.06	44	51	40	1.28	**31**	**44**	-13	1.41	56
Terraces Apartment Homes[8]	223				88	69	1.29	**54**	**78**	-24	1.45	101	85	47	1.29	**37**	**101**	-64	2.76	130
Holly Street Village[9]	223				175	144	1.33	**108**	**107**	1	0.99	142	185	125	1.33	**94**	**139**	-45	1.48	185
Broadway Grand	223				72	36	1.57	**23**	**32**	-9	1.42	50	85	34	1.57	**22**	**42**	-20	1.93	66
Archstone at Del Mar Station	223				98	66	1.31	**50**	**66**	-16	1.32	86	102	60	1.31	**46**	**86**	-40	1.87	113
The Sierra	223				121	74	1.47	**50**	**66**	-16	1.31	97	166	90	1.47	**61**	**86**	-25	1.40	126
Terraces at Emery Station	223				159	112	1.12	**100**	**30**	70	0.30	34	138	98	1.12	**87**	**39**	48	0.45	44
Victor on Venice	223				61	51	1.17	**44**	**33**	11	0.76	39	76	59	1.17	**50**	**43**	7	0.85	50
343 Sansome[10]		710			316	103	1.43	**72**	**355**	-283	4.93	508	333	84	1.43	**58**	**341**	-283	5.83	488
Convention Plaza		710			514	214	1.17	**183**	**481**	-298	2.63	563	491	193	1.17	**165**	**462**	-297	2.80	541
Charles Schwab Building		710			510	104	1.77	**59**	**498**	-439	8.45	881	401	76	1.77	**43**	**479**	-436	11.17	848
Park Plaza		710											53	36	1.27	**28**	**95**	-67	3.36	121
Park Tower		710			617	383	1.20	**319**	**645**	-326	2.02	774	566	374	1.20	**312**	**620**	-308	1.99	744
Oakland City Center		710			248	128	1.28	**100**	**297**	-197	2.96	380	221	75	1.28	**59**	**286**	-227	4.88	366
180 Grand Avenue		710			184	96	1.21	**80**	**271**	-191	3.40	328	143	79	1.21	**65**	**261**	-196	4.02	316
Emery Station East		710			298	151	1.14	**133**	**365**	-232	2.75	416	251	140	1.14	**123**	**351**	-228	2.86	400
181 Second Avenue		710			101	101	1.10	**92**	**77**	15	0.84	85	114	94	1.10	**85**	**74**	11	0.87	81
Oakland City Center			880										479	0	1.28	**0**	**93**	-93	Undefined	119
Paseo Colorado			820										1551	1208	1.57	**770**	**1856**	-1086	2.41	2914
Fruitvale Station			867										116	99	1.50	**66**	**102**	-36	1.54	153
343 Sansome[10]				936	356	41	1.43	**29**	**129**	-100	4.45	184								
Convention Plaza				936	259	62	1.17	**53**	**182**	-129	3.46	213	80	25	1.17	**21**	**63**	-42	2.97	74
Park Tower				936	430	94	1.20	**78**	**194**	-116	2.48	233	90	23	1.20	**19**	**67**	-48	3.55	80
Oakland City Center[11]				936																
Broadway Grand				936	316	141	1.57	**90**	**152**	-62	1.69	239	237	57	1.57	**36**	**53**	-17	1.46	83
Fruitvale Station				936									192	179	1.50	**119**	**54**	65	0.45	81
					5365	2403		**1911**	**4323**	-2412	2.26	5673	6508	3419		**2504**	**6011**	-3507	2.40	8389

1) ITE Use Codes are from the ITE Trip Generation Manual, Eighth Edition.
2) Actual total person trips trips is the total number of person trips during the peak hour at the study location. The estimated number of trips was adjusted for gender bias and different mode shares at each door. Locations with fewer than 30 surveyed trips during a data collection period were not analyzed because they were determined to have insufficient data to estimate mode shares.
3) Actual automobile person trips is the total number of person trips that used an automobile mode at each site.
4) Automobile occupancy was estimated from the total morning or afternoon survey responses at each site.
5) ITE-estimated vehicle trips were calculated using standard Trip Generation Manual (2008) trip rates.
6) The ratio of ITE vehicle trips to actual vehicle trips is undefined when the estimate of actual peak hour vehicle trips was 0.
7) ITE-estimated total person trips were calculated by multiplying the ITE-estimated vehicle trips by the average automobile occupancy for each site. This assumes that the ITE estimates are based sites with 100% automobile mode share.
8) PM data collection at Terraces Apartment Homes was from 3:30 p.m. to 6:30 p.m.
9) PM data collection at Holly Street Village was from 3:30 p.m. to 6:30 p.m.
10) AM data collection at 343 Sansome was from 6:30 a.m. to 9:30 a.m.; PM data collection at 343 Sansome was from 4:00 p.m. to 6:30 p.m.
11) Results were not reported for the Oakland City Center coffee shop because there were fewer than 30 surveys in both the AM and PM study periods.

predictors of trip frequency and mode choice (see Appendix B). Guided by this evidence, the Team created a database of potential explanatory factors—variables that may predict the difference between actual trip counts at smart-growth development projects and trip estimates based on ITE rates. The Team focused on variables that would be relatively easy to measure or acquire using data from the U.S. Census, Google Maps, transit agencies, and other sources.

In order to create theoretically-sound models that are also practical to use, the Team tested many variables and many model structures. Because smart growth characteristics are commonly found together (e.g. it is unusual to find high population density without frequent transit service, and vice versa), many of the potential explanatory factors were statistically correlated, a problem in fitting linear regression equations. To address this problem, the Team settled on a two-stage approach, which was presented to and approved by the Practitioners Panel. In the first stage, a smart growth factor is calculated as a function of eight site and context characteristics (see Table 8). In the second stage, the calculated smart growth factor, a dummy variable for the particular land use, and a dummy variable for proximity to a university are plugged into a linear regression equation to estimate an adjustment factor (see Table 9). The equations, their derivation, and their application are discussed in detail in Appendix F.

Table 8. Variables in Smart Growth Factor Equation

Residential population within a 0.5-mile, straight-line radius (000s)
Jobs within a 0.5-mile, straight-line radius (000s)
Straight-line distance to center of major central business district (CBD) (miles)
Average building setback distance from sidewalk (feet)
Metered on-street parking within a 0.1-mile, straight-line radius (1=yes, 0=no)
Individual PM peak-hour bus line stops passing within a 0.25-mile, straight-line radius
Individual PM peak-hour train line stops passing within a 0.5-mile, straight-line radius
Proportion of site area covered by surface parking lots (0.00 to 1.00)

Table 9. Variables in Adjustment Factor Equation

Smart-Growth Factor
Office land use (1 = yes, 0 = no)
Coffee shop land use (1 = yes, 0 = no)
Multi-use development (1 = yes, 0 = no)
Within 1 mile of a university (1 = yes, 0 = no)
Office land use (1 = yes, 0 = no)

The AM and PM models were validated using the sites with available vehicle trips counts that were not used in developing the equations. 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. This comparison showed that the models predicted the smart-growth adjustment accurately at some validation sites (e.g. the model ratio was within 50% of the observed ratio) 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). Thus, the models produced conservative adjustments relative to ITE-based trip estimates.

It is important to note that the resulting models are only appropriate for analysis at single-use sites or single land uses that are a part of multi-use sites and only for such sites that are in smart-growth areas. In consultation with the Practitioners Panel, the Team defined specific criteria that should be met in order to apply the model (Table 10). For sites that do not meet these criteria, the models may overestimate the adjustment to ITE rates and thus underestimate vehicle trips.

Table 10. Criteria for Applying Models

Land Uses	ITE Trip Generation Land Use Codes: Residential (220, 222, 223, 230, 232), office (710), restaurant (925, 931), and coffee/donut shop (936); potentially applicable to retail land use codes.
Development	▪ The area within a 0.5-mile radius of the site is mostly developed, and ▪ There is a mix of land uses within a 0.25-mile radius of the site, and ▪ 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, and ▪ There are no special attractors within a 0.25-mile radius of the site (e.g., stadiums, military bases, commercial airports, etc).
Transit service	During a typical weekday PM peak hour, there are at least 10 bus stop locations on all bus lines that pass within any part of a 0.25-mile radius around the study site, or 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.
Pedestrian or bicycle infrastructure	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), or there is >50% sidewalk coverage on streets within a 0.25-mile radius of the site.

The UC Davis Project Team developed a spreadsheet tool that practitioners can use to apply the method. The first page of the spreadsheet outlines the criteria for applying the method. The practitioner enters data for the development project for each of the criteria. If the development project meets the criteria, the practitioner can then move to the second page, where he or she enters additional data needed by the models, and the spreadsheet then calculates the adjustment factors and trip generation estimates. The Practitioners Panel reviewed draft versions of the spreadsheet tool and made many useful suggestions to improve its usability. The spreadsheet tool is available at:

http://downloads.ice.ucdavis.edu/ultrans/smartgrowthtripgen/CA_SGTG_Spreadsheet_Tool_1.0.xlsx

5. Conclusions

This project addressed the need for a methodology that practitioners can use to estimate multi-modal trip-generation rates for proposed smart-growth land use development projects in California. After identifying and assessing existing alternatives to ITE trip generation rates, the UC Davis Project Team concluded that a new method, based on new data, was needed. The Team collected multi-model trip-generation data at 30 locations in California and used these data, along with available data from other studies, to develop a smart-growth trip-generation tool.

This tool represents a significant step forward, but additional work is needed. It is likely that the small-sample models do not account for all of the complex variation in sites, including different levels of economic activity at particular locations. Additional data collection is needed at a wider range of land uses and at sites with a wider range of characteristics. Given enough data, it may be possible to develop separate models for different land use categories to account for the specific ways that smart growth characteristics affect trip generation for those uses. In addition, given enough data, it may be possible to develop models that estimate trips directly as a function of site characteristics rather than as an adjustment to ITE-based estimates. Ultimately, the results of this and future studies will benefit practitioners seeking to evaluate developments that support sustainable transportation and land use systems.

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California Smart-Growth Trip Generation Rates Study

Final Report

Appendix A

Institute of Transportation Studies

University of California, Davis

Davis, CA 95616

Summary of Findings and Recommendations

Regarding Key Definitions

Rachel Maiss, Richard Lee, and Susan Handy
November, 2009

Overview

The goal of this task is to establish definitions to guide the identification of studies and practices that have direct relevance to the development of the "Trip-Generation Rates Spreadsheet for Smart-Growth Land-Use Projects". The overall project goal is to create and disseminate a spreadsheet-based tool for estimating trip generation rates for smart growth land use projects.

Smart Growth Defined

The Smart Growth Network, a joint activity of the U.S. Environmental Protection Agency (EPA) and several non-profit and government agencies, identifies ten principles of smart growth. In recent years, these have gained wide circulation as a definition of this complex development concept. We acknowledge this widely accepted set of descriptors, and define smart growth developments as land use projects compatible with the ten principles propounded by Smart Growth Network to a significant degree. In other words, a smart growth project serves to directly or indirectly:

- Mix land uses
- Take advantage of compact building design
- Create a range of housing opportunities and choices
- Create walkable neighborhoods
- Foster distinctive, attractive communities with a strong sense of place
- Preserve open space, farmland, natural beauty, and critical environmental areas
- Strengthen and direct development toward existing communities
- Provide a variety of transportation choices
- Make development decisions predictable, fair, and cost effective
- Encourage community and stakeholder collaboration in development decisions

It is noteworthy that these principles (and many smart growth proponents) point to benefits apart from transportation. For example, fostering a strong sense of place and encouraging community collaboration are non-transportation goals with clear societal benefits. Moreover, some of the ten principles with transportation implications also embody other, non-transport benefits: e.g., compact housing is often more affordable; and mixing residences and local shops and services are useful to residents even if they drive to them.

Smart Growth Transportation Principles

Closer examination reveals that four of the ten Smart Growth principles are of particular importance to transportation planning in general and this project's focus on trip generation in particular. While each of these four principles is distinct, they are synergistic in their effect on travel behavior.

- *Take advantage of compact building design:* This is a synonym (perhaps a euphemism) for development density, which countless studies over many decades has shown to be positively correlated with transportation modes other than the auto.
- *Mixed land uses*: This smart growth principle is important to take into account when estimating trip generation, as an appropriate diversity of land uses within one site tends to foster internal trips and, depending on site design, reduce overall vehicle trips.
- *Creation of walkable neighborhoods*: This principle is relevant to trip generation as walkable neighborhoods tend to encourage non-motorized travel, thus reducing overall vehicle trips. Density and land use mix play a fundamental role in the creation of walkable environments (by shortening trips and providing nearby destinations), but the presence of sidewalks, footpaths and bikeways providing direct routes between related land uses is also an essential component of walkability.
- *Provision of a variety of transportation choices*: This principle pertains to trip generation in the sense that providing various transportation choices and alternatives to the automobile can encourage reduction in overall vehicle trips. Walkability represents an essential first step toward providing transportation choice, and provision of walkways is a smart growth element that development projects should be expected to provide regardless of the scale of development.

Multi-Modalism: A Key Smart Growth Element Defined

This last principle, "provision of a variety of transportation choices" may be summarized, in a word, as *multi-modalism*. The term "multi-modal" implies the availability and use of a variety of travel modes, including personal vehicles (single occupancy vehicles and high occupancy vehicles), transit (rail, bus, etc.), and non-motorized modes (bike, walk, etc). This term is pertinent to this project as smart-growth development projects aim to foster a relatively high degree of multi-modalism and thereby reduce overall vehicle trips.

While facilities for walking and bicycling can and should be provided at the project scale, many transportation choices – e.g. rail and bus rapid transit, and complete pedestrian and bike networks – require government funding, coordination, and implementation at a regional scale. Development projects can make *provision* for non-automobile choices, but cannot on their own *provide* them.

For purposes of this study, "multi-modal" is defined as transportation systems (and analysis of such systems) that includes, at minimum, auto, transit and non-motorized (pedestrian and bicycle) travel. The need for, and feasibility of, more refined modal categories, e.g., distinguishing auto driver vs. auto passenger, types and levels of transit service, and bike vs. walk, will be determined at the conclusion of Task 4 (Expert and Practitioner Panel Review).

Litman: Further Defining Smart Growth from a Transportation Perspective

Todd Litman has recently published a summary analysis of the market for Smart Growth that includes an extensive definition of Smart Growth through the lenses of transportation planning.[1] For Litman, smart growth consists of land use development patterns that emphasize *accessibility* (the ability to reach destinations) over *mobility.* Smart growth also fosters modal diversity, as opposed to dispersed, automobile dependent development, which Litman equates to *sprawl*. Table 1 summarizes Litman's comparative analysis of these two development paradigms.

Litman views smart growth as applicable to a wide range of contexts, but notes that its form and associated transportation facilities and performance will be different in different metropolitan environments:

- **Urban Smart Growth** may entail medium- and high-density mixed-use development concentrated around transit stations, e.g., *transit-oriented development*.
- **Suburban Smart Growth** typically entails small-lot and low-rise, mixed-use, walkable neighborhoods, and is often called *new urbanism* or *neotraditional planning*.
- **Rural Smart Growth** typically entails development clustered in walkable *villages*, connected by ridesharing and public transit, and roads with adequate shoulders to accommodate bicycles.

Thus, while all smart growth development is, by definition, multimodal, the modes available and their degree of use (modal share) will vary.

Table 1 **Comparing Smart Growth and Sprawl** (Based on Litman 2009, Table 2)

Variable	**Sprawl**	**Smart Growth**
Density	Lower-density, dispersed activities.	Higher-density, clustered activities.
Growth pattern	Urban fringe (greenfield) development.	Infill (brownfield) development.
Land use mix	Homogeneous (single-use, segregated).	Mixed land uses.
Scale	Large scale. Larger blocks and wider roads. Less detail since people experience the landscape at a distance, as motorists.	Human scale. Smaller blocks and roads. Careful detail, since people experience the landscape up close, as pedestrians.

[1]Litman, T. (2009). "Where We Want To Be: Home Location Preferences And Their Implications For Smart Growth" Victoria Transport Institute, 18 September.

Variable	Sprawl	Smart Growth
Public services (schools, parks, etc.)	Regional, consolidated, larger. Requires automobile access	Local, distributed, smaller. Accommodates walking access.
Transport	Automobile-oriented. Poorly suited for walking, cycling and transit.	Multi-modal. Supports walking, cycling and public transit.
Connectivity	Hierarchical road network with numerous dead-end streets, and limited, unconnected walking and cycling facilities.	Highly connected (grid or modified grid) streets and nonmotorized network (sidewalks, paths, crosswalks and shortcuts)
Street design	Streets designed to maximize motor vehicle traffic volume and speed.	Streets designed to accommodate a variety of activities. Traffic calming.
Planning process	Unplanned, with little coordination between jurisdictions and stakeholders.	Planned and coordinated between jurisdictions and stakeholders.

Operationalizing Smart Growth Components for Trip Generation Analysis: The D-Factors

For more than a decade, transportation analysts in both academia and professional practitice have attempted to isolate and measure components of smart growth that reduce vehicle trip rates and related impacts. This body of research has come to be known as D analysis due the fact the many of variables can (with some creativity) be described with terms beginning with the letter D.

The most well known Ds are local land use variables that include **D**ensity, land use **D**iversity, pedestrian-scale **D**esign, access to regional **D**estinations, and **D**istance to Transit. Other D variables include **D**evelopment Scale, **D**emographics and Travel **D**emand Management.

The D-factor terminology may be traced to research led by Robert Cervero[2]. This research found that certain characteristics of neighborhoods affected the amount and mode of travel (measured in terms of vehicle trips and vehicle miles traveled). This effect was independent of household and demographic characteristics (income, household size, number of workers, etc.) typically used in vehicle trip generation equations. Related research has found that the D variables also affect transit ridership and non-motorized trips when they occur near rail transit stations.

[2] Cervero, R. and K. Kockelman (1997) "Travel Demand and the 3Ds: Density, Diversity, and Design," *Transportation Research D* 2:199-219. Other resources used to define these factors include Fehr & Peers' *Accurate Trip Generation Estimates for Mixed-Use Projects,* and Cervero and Lee's *The Effect of Housing Near Transit Stations on Vehicle Trip Rates and Transit Trip Generation.*

One conclusion of the D-research is that trip generation analysis for traffic impact studies should include adjustments to trip-generation rates to reflect the characteristics of the area surrounding the household. This finding is in one sense well-known and acknowledged: the ITE *Trip Generation* manual has been recommending such an adjustment in its last three editions. Nonetheless, an accepted process of operationalizing smart growth trip generation analysis is still under development. With SB 375 mandating that California Metropolitan Planning Organizations (MPOs) modify regional transportation planning to be sensitive to local land use factors, the policy incentives appear to be increasing.

The "D-factors" would appear to represent a reasonable basis for such a smart growth trip generation method, since they are measurable and demonstrably affect mode choice and trip generation. Developments that typically incorporate some or all of the D factors include infill development, cluster development, mixed-use development, and transit-oriented development, (See the Appendix for definitions of the terms).

The "D-factors" that seem highly relevant to this project include the following seven interrelated variables:

- *Diversity:* The extent to which the site mixes commercial, residential, and business land uses. Increased diversity of land uses can increase the amount of internal trips.
- *Density:* The density of a site, typically measured in units such as dwelling units or employees per acre or square mile, floor area ratio (FAR), etc. Higher density developments tend to yield fewer vehicle trips per unit of measurement.
- *Design:* Specifically, design of the site's transportation networks, taking into account connectivity and walkability, both of which have the potential to reduce vehicle trips.
- *Destination-proximity:* "Accessibility to regional activities - development at infill or close-in locations reduces vehicle miles" of travel."[3] *and "*Accessibility to other activity concentrations expressed as the mean travel time to other destinations in the region."[4] The site's proximity and accessibility to interactive, compatible land uses. Land uses in close proximity to other compatible land uses tend to generate fewer vehicle trips and lower rates of vehicle miles traveled. Density and diversity both contribute to destination-proximity.
- *Distance to transit:* The site's proximity to transit stations. Closer proximity increases the feasibility of transit usage, thus reducing vehicle trips. Higher densities support more intensive transit service, thereby potentially increasing the amount of people using transit.
- *Development scale:* the size of a development project. "A 'critical mass' of acres, population, jobs provides a sufficient variety of options, and balance of opportunities."[5] Generally the larger the project, the greater the internalization of trip making, although internalization of trip making depends on the density and diversity of land uses.
- *Demand Management*: pricing and incentives for using non-auto modes can, under the right conditions, dramatically reduce auto use. Diversity, density,

[3] Walters, J., Powerpoint to the SB375 Regional Targets Advisory Committee, Feb. 3, 2009.
[4] Walters, J. and R. Ewing. (2009) "Measuring the Benefits of Compact Development on VMT and Climate Change," *Environmental Practice*, September.
[5] Walters, J., Powerpoint to the SB375 Regional Targets Advisory Committee, Feb. 3, 2009.

design, and destination-proximity all contribute to “the right conditions.”
- *Demographics:* factors such as household life-cycle, income and auto ownership indisputably affect travel choices, although demographics are not directly tied to land use

Each of these seven Ds is defined and discussed in more detail below.

Discussion: Seven Critical D Variables: Characteristics, Scope and Measurement

The literature on neighborhood characteristics that affect trip generation is constantly evolving and new models of travel behaviors are always being investigated. That said, the variables described below define key land use characteristics that can be tied to a particular development project and that have been shown (via analysis of travel surveys and other empirical research) to affect trip-making and mode choice, and are therefore likely candidates for inclusion in a project-scale smart growth trip generation tool.

Density

Net *Residential Density* is measured in terms of households or dwelling units per acre. Ideally acreage should be that which is actually developed for residential uses, excluding roadways, open space and other undevelopable land. A wide body of research suggests that, all else being equal, denser developments generate fewer vehicle-trips per dwelling unit.

Similarly *Employment Density* is measured in terms of employees or building area per acre of land devoted to employment. While the research on the relationship between employment density and vehicle trip reduction is less clear than for residential density, transportation analysts generally believe that such a relationship exists.

Mixed-use or Land Use Diversity

A definition of mixed-use development (often abbreviated MXD) that encompasses many existing areas with interconnected, mixed land use patterns was developed by Ewing et al[6]. This definition is, in turn, based on the definition of “multi-use development” used in the Institute of Transportation Engineers’ (ITE) *Trip Generation Handbook* (2008):

> “A mixed-use development or district consists of two or more land uses between which trips can be made using local streets, without having to use major streets. The uses may include residential, retail, office, and/or entertainment. There may be walk trips between the uses.”

The American Planning Association (APA) defines mixed-use planning as aiming “to create pedestrian-friendly environments, higher-density development, and a variety of uses that enable people to live, work, play, and shop in one place, which can become a destination”.

Two types of mixed use may be distinguished:

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[6] Ewing, R. et al. (2008). Traffic Generated by Mixed-Use Developments – A Six-Region Study Using Consistent Built Environmental Measures. Paper Presented at 87th Meeting of the Transportation Research Board, January.

- *Jobs/Housing Fit or Balance* – Research suggests that residences and jobs in close proximity can reduce the number or distance of vehicle-trips generated by each use by allowing some work trips to be made on foot or by bicycle and reducing travel distances by auto or transit. This variable is often measured by measuring how closely a project or a project neighborhood (e.g. all land uses within a half-mile, or a ten-minute walk) matches the "ideal" mix of jobs and households. For example, in a region with three million jobs and two million households, the jobs/housing ratio would be 1.5.

- *Employment Diversity* – Research also suggests that a mix of basic employment activities (e.g. offices) and retail and service employment (e.g. shops and restaurants) can reduce vehicle use for trips that originate or terminate at a work site. This variable measures how closely a neighborhood matches the "ideal" mix of jobs and households, which is often assumed to be the ratio of jobs to non-retail jobs measured across the region as a whole. In other words, a project or project neighborhood with the same ratio of retail/non-retail ratio as the region would be considered optimal in terms of internalizing trips and reducing vehicle travel.

Walkable Design

Many pedestrian and bicycle improvement projects are based on the assumption (supported by some research findings) that improving the walking/biking environment will result in more non-auto trips and a reduction in auto travel. The difficulty with using this variable in trip generation is that there are many variables that influence the pedestrian experience and it is difficult to identify a single definition that captures them all. The walkability used in some applications (e.g. the EPA SmartGrowth INDEX land use analysis software) focuses on the *presence, density,* and *directness* of pedestrian paths.

Perhaps reflecting the difficulty of capturing all relevant aspects of walkability, the walkable design variable, when isolated, usually has the weakest influence on the tripmaking of the D variables. That said, design for non-motorized transport seems to have important synergistic effects in conjunction with density and diversity[7].

Destination Accessibility

Research shows that, all else being equal, households and non-residential activities situated near regional centers of activities generate fewer auto trips and VMT than households located far from destination centers. When comparing different potential sites for the same type of development, this variable is very important. This variable can be quantified by estimating the total travel time to all destinations/attractions.

Sensitivity to variations in regional accessibility is characteristic of most well-calibrated and validated four-step travel demand models and therefore modeling can be used to estimate this D variable. Under this approach, the model calculates the total travel time (or generalized cost) of travel from one zone to all destinations of interest in a region (i.e., jobs or retail opportunities). Travel time contours by mode (e.g., the number of jobs

[7] Cervero, R. and R. Gorham. (1995) " Commuting in Transit Versus Automobile Neighborhoods" *Journal of the American Planning Association,* 61(2):210-225.

or retail opportunities within 30 minutes of a site by car or transit) are examples of Destination Accessibility measures.

Although travel demand models provide a reasonable estimate of regional accessibility, they treat local accessibility – destination accessibility within or nearby a neighborhood – in a cursory way. Most such models include a crude measurement of “intra-zonal” trips captured by nearby destinations. Examining both local accessibility, as influenced by diversity and design within close proximity of the development project, and regional accessibility, reflecting land use patterns and transportation connections throughout the region, is important in estimating vehicle trip generation and VMT.[8]

Distance to Transit

Development near transit that is higher density and has an appropriate diversity of land uses in an environment designed for easy walking and biking is likely reduce auto use for several interrelated reasons.

- Better regional accessibility – especially via high-capacity transit, reduces auto commuting

- More local opportunities lessen the need for auto use

- Diversity of uses near transit stops encourages station-area residents to ride transit by allowing “trip chaining” (i.e., walking to nearby shops en route to residences from stations after work).

There may also be reduced vehicle trips and vehicle miles of travel due to:

- Fewer autos owned
- More trips by walking
- Shorter auto trips

Detailed analysis by the Metropolitan Transportation Commission (MTC) of its 15,000 household Bay Area travel survey data base from the year 2000 confirms the effects of proximity to high quality transit services, even when accounting for other D variables such as density. MTC found that residents living within a half mile of a rail transit or ferry station are four times more likely to use transit than those living more than a half mile from a transit or ferry station. This is consistent with findings on variation in modal splits by distance to transit found by Cervero (1994) and Lund et al. (2003). The Bay Area survey results show that residents living and working within a half mile of transit or ferry stations average 42% of their daily trips by transit, walking or biking, Nearly a third of households within a half mile of ferry or transit stations have no vehicle. Households within a half mile of ferry or rail transit stations generate half the VMT of suburban and rural residents.

Development Scale

[8] Handy, S. (1996) “Understanding the Link Between Urban Form and Nonwork Travel Behavior,” *Journal of Planning Education and Research*, 15(3):183-198 .

Research indicates that a “critical mass” of acres, population, and jobs provides a sufficient variety of options and balance of opportunities.[9] Development Scale affects trips due to the fact that, all else equal, the larger the scale of a development, the higher the percentage of trips likely to be internalized. The degree to which this occurs will depend on factors such as the first four D variable of density, diversity, design and regional destination proximity. In addition, in larger the scale of the development, the internalized trips are more likely to made by automobile rather than non-motorized modes, given the increase in travel distance, all else equal.

Demand Management

Travel Demand Management (TDM) -- pricing and other incentives for the use of alternate modes -- can also have a marked effect on travel behavior. The table below, which is focused on parking demand as an example, shows that the potential effectiveness of such a TDM is significant. The difficulty with incorporating TDM in trip generation analysis arises from the fact that unless TDM performance measures are established by law or contract (a rarity in California today) the predictability of TDM implementation and thus effects is uncertain. In sum, TDM can significantly alter travel behavior, but absent a legally binding agreement, many analysts would not be comfortable relying on substantial vehicle trip reductions based on TDM.

Table 2 Estimated Effects Demand Management Strategies on Parking Demand

Demand Management Strategy	**Potential Parking Reduction**	**Cost to Implement for Developer**
Shared Parking	10-20%	More detailed parking analysis during planning stages
Transit Pass Purchase	5-20%	Developer includes in price of building, overall decrease in cost because of fewer parking spaces
Charging for Parking	5-20%	Charge tied to use of parking
Unbundled Parking	5-10%	None
Car-Sharing	2-5%	Developer dedication of parking spaces to car-sharing operations
Source: Fehr & Peers, October 16, 2009, Draft Memo, *Smart Growth Parking Requirements and Strategy Review*		

Demographics

Demographic variables – e.g., family size, life-stage, income class, and vehicle ownership -- clearly affect trip generation as well as vehicle trip-making and vehicles

[9] Walters, J., Powerpoint to the SB375 Regional Targets Advisory Committee, Feb. 3, 2009.

miles traveled.   The main issue for trip generation analysis arises from the fact, with some notable exceptions (e.g., age-restricted and income-restricted housing) it is extremely difficult to forecast demographic characteristics of residents and users of new development projects. Thus while the predictive value of demographic variable may statistically valid, the challenge of accurately predicting them may diminish the value of demographic variables in practice.

Conclusion

While the ongoing literature review may reveal other key variables beyond those discussed, the seven Ds as defined above represent a reasonable guide for identification of studies and practices that have direct relevance to the development of the end goal for this project, a tool capable of more accurately analyzing the trip generation characteristics of smart growth land use development projects.

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Appendix B

Institute of Transportation Studies

University of California, Davis

Davis, CA 95616

Appendix “B”

Annotated Literature Review of Land Use-Transportation Relationships

Table of Contents

This document builds on an annotated literature review initially prepared in 2010 by Susan Handy, Richard Lee, and Rachel Maiss (UC Davis Institute of Transportation Studies) for the Caltrans-funded “Trip-Generation Rates Method for Smart Growth Land Uses in California” project.

During 2011, Jerry Walters and Richard Lee (of Fehr & Peers Consultants) augmented this review with additional literature relevant to another Caltrans-funded project “Improved Data and Tools for Integrated Land Use-Transportation Planning in California” project.

Terry Parker, Caltrans’ HQ project manager for both studies, provided input and review of both phases.

A. Overview

This literature review provides an annotated synopsis of studies produced by the transportation research and practitioner communities on relationships between the characteristics of the built environment and the generation of travel demand. It also identifies prominent tools used by planners and engineers to integrate these relationships into planning and project evaluation processes employed by local and regional governments and state agencies. The review was conducted to support two Caltrans-sponsored projects underway to create improved planning tools for evaluating: transportation impacts of smart growth land uses; and integrated local and regional land use/transportation planning. This document represents the combined work of the study teams working on the two projects.

The review includes literature found in online research resources such as TRIS/TRID, Google Scholar and the archives of *Transportation Research Record*. Bibliographies of key documents were reviewed for additional resources. Additionally, pertinent literature with which the researchers are familiar was included. The literature acquired was assessed regarding the development of analysis tools for assessing relationships between the built environment and travel demand, including vehicle trips and vehicle miles of travel (VMT).

B. Organization

This review divides available literature identified into two types: (1) "empirical research," and (2) "applied methods." The first category contains studies that focus on quantitatively analyzing the relationship between urban form and travel behavior, as well as meta-analyses and large-scale reviews of such literature. The second category contains literature that describes methods, models, and tools used by practitioners for improved understanding of the built environment and travel behavior, or specific elements thereof. Though the literature was divided as logically as possible, some overlap may exist between these categories. Where available, links to documents are provided.

Studies especially relevant to the site-specific smart growth trip-generation rates methodology effort are preceded by a single asterisk (*). Those especially relevant to integrated land use/transportation analysis tools and scenario planning processes are preceded by a double-asterisk (**).

C. Overview and Conclusions

The literature reviewed shows great diversity in the approaches taken by theorists and practitioners in studying relationships between the built environment and travel behavior in the U.S. Even so, there appears to be some consensus regarding key relationships useful for performing analysis of potential effects of alternative land use and transportation strategies on travel at the local and regional levels. This type of analysis is needed to develop and assess land use and transportation planning scenarios and

* Study is relevant to travel related to site-specific "smart growth" land use projects.
** Study is relevant to integrated land use and transportation analysis and scenario planning.

implementation programs for integrated “Blueprint” planning and Sustainable Communities Strategies (SCSs), which are required as part of Regional Transportation Plans (RTPs) for California’s MPOs under SB 375[1]. There is also interest by cities, counties, special interest and community groups, developers, etc. in such strategies.

The body of available literature indicates that certain built environment variables, such as development density, land use mixture (diversity), and design for walkability and transit access, can have an important influence on travel behavior expressed in travel mode, vehicle trips (VT) and vehicle miles traveled (VMT). However, the built environment does not represent the only, nor even the most important, determinant of household travel. Demographic variables, especially income, household size and composition, and automobile ownership/availability, have a larger influence on travel behavior. Even so, local land use and transportation variables are important because they are more susceptible to policy influence in the US political context compared to variables such as income, auto ownership and household size and composition. It should also be noted that certain of these variables, such as auto availability, can be estimated as a function of urban form and demographic variables (e.g., Holtzclaw et al, 2007).

A variety of studies indicate that if local variables - such as density, diversity, design, and accessibility to significant destinations via transit and non-motorized modes - are all enhanced simultaneously in urban areas, reductions in vehicle trips and vehicle miles traveled on the order of 25 percent or greater per household are possible in those areas.

The literature suggests that some of the explanations for lower VT and VMT rates in such “smart growth” areas are due to “self selection” – people wishing to reduce their need to drive seek out urban areas where this desire can be realized. The self-selection process occurs both in residential choice and well as the choice of workplace and shopping destinations. The self-selection process implies that, to the extent that there may be underserved demand for less auto-centric urban environments in a given region, estimates of the elasticity of VT and VMT with respect to the built environment provide better predictions of the changes that could occur if additional “less auto-centric urban environments” are built.

A parallel study (Vision California) suggests that “smart growth” development of all types may be significantly under-provided in local plans, indicating that there will be substantial unmet demand for “smart growth” in California in the decades ahead. This implies that if more “smart growth” development is built, there will be a sufficient supply of “self-selectors” to live, work, and shop in them. This attenuates the need to adjust for self-selection, at least in California. Self-selection is still important from a policy

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[1] See the California Transportation Commission’s *2010 Regional Transportation Guidelines*, Chapter 3 at: http://www.catc.ca.gov/programs/rtp/2010_RTP_Guidelines.pdf

standpoint, in that the under-supply of smart growth development needs to be addressed if we want to take full advantage of the connection between the built environment and travel behavior.

Among local land use factors affecting travel demand, the literature indicates that access to regional destinations via non-automobile modes is the single most important built environment factor. Development in areas of high accessibility— e.g., in or near central cities—tends to produce lower VMT per capita compared to even dense mixed-use development located on the "fringe." Diversity – land use mixture -- is also influential, though identifying appropriate land use mixtures can be challenging. (For example, a restaurant located near an office or home may attract walking trips, while a furniture store might not - even though both may be classified as "retail" in land use databases and local zoning codes.) **Density (of population and employment), and design or connectivity (especially when measured as the density of intersections and/or streets, bicycle facilities, and sidewalks), are often highly correlated variables** (which often results in only one variable appearing significant in regression analyses). An optimal method of sorting out these intertwined variables has not yet emerged in the literature reviewed, though methods have been developed by researchers.

Another set of issues the literature does not fully address include the transferability of relationships between built environment and travel behavior: there is variation across metropolitan areas regarding alternatives to automobile travel. **Opportunities to lower levels of VT and VMT are greatest where urban areas and transit systems offer accessibility that provides truly attractive alternatives to automobile travel.**

The land use–travel literature, though vast, is lacking in longitudinal and retrospective studies. Very few "before and after" studies exist, and the literature remains dominated by cross-sectional studies and forecasting model analyses. Another limitation is that the current body of literature is almost entirely comprised of studies based on data that is at least a decade old. And, only a few are based primarily on California data.

Thus, the data collection and analyses being conducted for the two Caltrans-funded data and tools development projects are important to advancing the state-of-practice in California. These projects are providing locally-derived and up-to-date quantitative data regarding land use/travel relationships. The "Improved Data and Tools for Integrated Land Use-Transportation Planning in California" project (SACOG, Fehr & Peers Consultants, UC Davis' ULTRANS, and Caltrans) has made these relationships available for use in "sketch-planning" analysis tools, GIS-based "visioning" software, and travel demand modeling.[2]

[2] http://ultrans.its.ucdavis.edu/projects/improved-data-and-tools-integrated-land-use-transportation-planning-california

The "Smart Growth Trip-Generation Methodology" effort by researchers at the Institute of Transportation Studies at UC Davis will provide a methodology for use in preparing transportation impact analyses of proposed "smart growth" land use development projects in California (for which ITE's suburban-based vehicle trips estimation data are not applicable, according to the ITE Trip Generation Handbook, 2004).

Such data and tools will be useful for integrated regional Blueprint scenario planning, preparing and analyzing Sustainable Communities Strategies and Regional Transportation Plans, as well as for local land use General and Specific Community planning and smart growth project implementation.

A. Empirical Research

- *Arrington, G. B. and Cervero R. (2008). **Effects of TOD on Housing, Parking, and Travel**, Transit Cooperative Research Program (TCRP) Report 128. http://144.171.11.107/Main/Public/Blurbs/160307.aspx

The objectives of this research were to learn more about the behavior and motivation of TOD residents, employees, and employers in their mode choice, as well as identify and recommend use of best practices to promote transit ridership in TODs. An extensive literature review was conducted regarding the TOD travel behavior and motivation. Unveiled in this review were the findings that transit system extensiveness, parking prices, and traffic congestion are all positively correlated with transit ridership. Relative transit travel time to auto travel time is more important to ridership than any land use factor. Aside from this, the most effective way to increase TOD transit ridership is to increase development densities in close proximity to transit. Also discovered was a lack of information regarding TOD trip generation characteristics, as the grid patterns typically associated with the dense development within TODs make it more difficult to conduct trip counts. Overall, it was found that policy factors that most strongly influence transit ridership in TODs include transit service levels, prices, and parking supply and costs.

Beyond the literature review, the study aimed to provide more information regarding vehicle trips generated by TODs, by collecting empirical trip generation data at a representative sample of TODs. Seventeen residential case studies were conducted in four metropolitan areas of the U.S.: (1) Philadelphia/Northeast New Jersey, (2) Portland, OR, (3) Washington D.C., and (4) the East Bay of the San Francisco Bay Area. Six of the surveyed projects included ground-floor commercial, but were primarily residential, and none of the projects were immediately accessible to a freeway interchange. Based on these counts, over a weekday period residential TODs averaged 44% fewer vehicle trips than estimated by ITE (based on a weighted average). The data collected by these counts are made available in the report. Additionally, the researchers ran a multivariate regression analysis to predict trip generation rates of residential TODs based on (1) distance of the project to the central business district, (2) distance of the project to a transit station, (3) residential densities around the station, and (4) parking provision. The

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bivariate relationships between residential TOD trip generation and other variables were weak and statistically insignificant.

Residential density within ½ mile of the transit station proved to be the most explanatory of the variables included in the regression. Thus, the effect of increased parking provision due to overestimating trip generation is discussed. As increased parking typically leads to decreased density (as previously mentioned, the most explanatory predictor of trip generation for TODs), the implications of overestimating trip generation rates for TODs are significant. Essentially, a feedback cycle is created in which developers decide to decrease density and increase parking provision at their TODs in order to get their development approved, which in turn leads to less transit use than originally anticipated by the TOD, and reaffirms initial concerns regarding the traffic impacts of the development. Thus, more accurate predictions of traffic generated by TODs are necessary in order for TODs to reach their full potential. This report provides valuable data that can serve as a starting point in putting together a tool that more accurately estimates trip generation for smart growth type developments.

- ******Boarnet, Marlon G. (2011). **A Broader Context for Land Use and Travel Behavior, and a Research Agenda.** *Journal of the American Planning Association*, 77:3, 197-213

Planning studies of land use and travel behavior focus on regression analysis of travel as a function of traveler demographics and land use near study subjects' residences. Methodological debates have tended to focus almost exclusively on the possibility that persons choose their residence based on how they wish to travel. This longer view steps back from the confines of the regression-based literature to explain the historical roots, methods, and results of the literature, and to assess how the land use–travel literature must be transformed to be more relevant to planning.

The article acknowledges the many prior summaries and meta-analyses of the impact of land use on travel. Its primary intent is not to summarize the results of past studies, but rather to explain how a literature that has become fundamental to planning scholarship is failing to be sufficiently planning-focused. It then describes how the literature can be transformed to address the planning challenges of today and tomorrow.

Over 100 articles are summarized, covering transportation methods from the dawn of the interstate highway era to topics that include program evaluation, land development, and cognitive aspects of travel behavior. The primary focus is on the land use and travel literature, but the review and analysis is broad ranging and places the literature and its challenges within the broader context of recent developments in the social sciences, planning, policy, and electronic data collection.

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Progress on three research frontiers is needed to move the land use–travel literature forward: First, behavioral models of land use and travel must expand to consider how land is developed, how places are planned, and how cities are built. Second, the land use–travel literature should build a robust retrospective program evaluation tradition, which is currently almost completely absent in a scholarly field dominated by cross-sectional hypothesis tests and forecasting models. Third, economic social welfare analysis must be carefully researched, including questions of preferences for neighborhood types and whether such preferences are fixed or malleable.

The article concludes by noting that planning is fundamentally about city building, and the literature and practice on land use and travel behavior should adapt to better support city building. This requires both a serious commitment to social science research and planning's characteristically broad view of context, problem, and place. In an era of climate change, and amidst debates about sustainability, the land use–travel literature must more aggressively examine the process of plans and place-making, evaluate the increasingly innovative transportation policies being implemented at the local level, and develop methods that allow more informed discussion about the costs and benefits of transportation policies.

- **Boarnet, M., Nesamani, K.S., & Smith, C. (2003). **Comparing the Influence of Land Use on Nonwork Trip Generation and Vehicle Distance Traveled: An Analysis Using Travel Diary Data.** Transportation Research Board, 83rd Annual Meeting.
  http://www.its.uci.edu/its/publications/papers/CASA/UCI-ITS-AS-WP-03-1.pdf

This article examines the relationship between land use and non-work trip generation and vehicle miles traveled (VMT). The authors hypothesize that land use impacts VMT more than it impacts trip generation. They use travel survey data to test this hypothesis. Portland Travel Diary data are used, which include information regarding ethnicity, income, employment, and a "pedestrian environment factor" based on the area's level of pedestrian infrastructure and design. Further, census data for the Portland region were examined, in addition to transportation network data from Portland's Regional Land Information System. The authors used regression techniques to model non-work vehicle trip frequency and VMT separately, both as functions of socio-demographic variables, and land use variables. Three of the "D-factors" were taken into account.

First, density was measured by population density within the respondent's census tract. Second, employment density, and retail employment density within the respondent's census tract served as indicators of land use diversity. Finally, design was measured by the percent of the street grid comprised of four-way intersections within a ¼ mile of the respondent's home. Based on their models, the authors conclude that income plays the largest role in determining both trip generation and VMT. However, after income is taken into account, the effect of land use variables is comparable to that of other socio-demographic variables. Ultimately, the authors' initial hypothesis was rejected in favor of the conclusion that land use variables have a similar effect on both VMT and trip generation.

- **Cambridge Systematics, Inc. (2009). **Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions***.* Washington D.C.: Urban Land Institute.

Moving Cooler is a study designed to analyze the potential for different strategies to reduce transportation related greenhouse gas (GHG) emissions in the United States. Various greenhouse gas (GHG) reducing strategy bundles are explored and analyzed. GHG reductions are estimated from reductions in vehicle miles traveled (VMT) and improvements in system efficiency. The bundles are analyzed at two levels of deployment: (1) aggressive, and (2) maximum. The bundle that is most reflective of the VMT reduction strategies examined by projects attempting to explore the relationship between land use and transportation is the "Land-Use/Transit/Non-Motorized Bundle." This bundle could potentially achieve significant GHG reductions through reduced automobile dependence by 2050. Specifically, GHG emissions could be reduced by up to 9% under aggressive deployment (assuming 54% of new development by 2050 is dense development of 5 or more units per acre), and up to 15% under maximum deployment (assuming 90% of new development by 2050 is dense development as defined above). Specific explorations of VMT reductions achieved through each bundle are not provided.

- **Cervero, R. (2007). **Transit-Oriented Corridors**. *The Transportation/Land Use Connection,* T. Moore, P. Thornes, B. Appleyard, Planning Advisory Service Report Number 546/547, pp. 136-137.

The author notes that "atomized" transit-oriented development (TOD) – i.e., development around a single transit station – has not produced significant regional benefits – reduced congestion, improved air quality, and land conservation. In fact, isolated TODs in a sea of auto-oriented development may be counter-productive, creating pockets of congestion as residents beyond the TOD drive to and through it. What is needed is a sufficient number of TODs aligned in a corridor, six to eight miles in length that will enable many trips to and from a TOD to also be made by transit. The author suggests that Transit Oriented Corridors (TOCs) on this scale are the important planning construct for analyzing the effectiveness of the TOD concept. Stockholm, Sweden is cited as an example of successful implementation of TOC; over decades planners there worked to coordinate development along linear axes, forming a "necklace of pearls."

TODs within the corridor can be specialized toward employment or housing, or mixed, but ideally the resulting corridor land use pattern will result in high transit use in both directions, facilitating both regional goals and efficient transit operations.

- **Cervero, R; Duncan, M (2006). **Which Reduces Vehicle Travel More: Jobs-Housing Balance or Retail-Housing Mixing?** *Journal of the American Planning Association,* Autumn 2006, 72; 4; 475-490

Which land-use strategy yields greater reductions in vehicular travel: improving the proximity of jobs to housing or bringing retail and consumer services closer to residential areas? The authors' probe this

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** Study is relevant to integrated land use and transportation analysis and scenario planning.

question by examining the degree to which job accessibility is associated with reduced work travel and how closely retail and service accessibility is correlated with miles and hours logged getting to shopping destinations. Based on data from the San Francisco Bay Area, they find that jobs-housing balance reduces travel more, by a substantial margin. The article concludes by discussing policy measures that have been introduced in California to bring housing, workplaces, and retail centers closer together. The authors document an inverse relationship between jobs housing balance and VMT of 0.05.

- Chatman, Daniel G. (2003). **How Density and Mixed Uses at the Workplace Affect Personal Commercial Travel and Commute Mode Choice.** *Transportation Research Record, 1831,* 193-201.

This paper describes a model that examines the relationship between land use characteristics at the workplace and commute and commercial travel choices. The built environment at the workplace is of particular interest as changes in land use patterns may be more politically feasible in these areas than in residential locations, and the self-selection problem is less of a concern when examining workplace locations. Data for the model is drawn from the 1995 Nationwide Personal Transportation Survey (NPTS). The test independent variables to estimate VMT are employment density and share of retail employment. A variety of demographic variables are included as controls. The model determined that high workplace density demonstrates a slight correlation with reduced VMT (with an increase of 10,000 employees per square mile yielding a 0.5 mile reduction in per capita personal commercial VMT), and retail at the workplace did not demonstrate a statistically significant correlation with VMT. However, a potential explanation for the latter finding could be that retail employment density is not a good indicator of activity accessibility as it does not include non-retail services such as banks or restaurants.

- **Chatman, D. (2009). **Residential choice, the built environment, and nonwork travel: evidence using new data and methods.** Environment and Planning A, Vol. 41, No. 5, pp.1072 – 1089.

This study confirms that residents of dense, mixed-use, transit-accessible neighborhoods use autos less. Recent studies have suggested that this relationship is partly because of the phenomenon of self-selection, i.e., households that prefer to use transit and walk or bike seek and find such neighborhoods. If this is the case, and if the number of such households is small, policies to alter the built environment may not influence auto use very much. The author argues that many of these studies are inconclusive on methodological grounds, and that more research is needed. A purpose-designed survey of households in two urban regions in California (the San Francisco Bay Area and San Diego region) is investigated, with the aid of a new methodological approach. The study finds that most surveyed households explicitly consider travel access of some kind when choosing a neighborhood, but that this process of residential self-selection does not bias estimates of the effects of the built environment very much. To the extent that it does exert an influence, the bias results both in underestimates and overestimates of the effects of the built environment, contrary to previous research. The analysis not only implies a need for deregulatory

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approaches to land-use and transportation planning, but also suggests that there may be value in market interventions such as subsidies and new prescriptive regulations.

- **Chatman, Daniel G. (August 2006). **Transit-Oriented Development and Household Travel: A Study of California Cities.** Institute of Transportation Studies, School of Public Affairs, University of California, Los Angeles. For the California Department of Transportation (Caltrans). http://www.policy.rutgers.edu/faculty/chatman/documents/TODs_and_travel_in_CA.pdf

This paper outlines a model of travel patterns of those living in transit-oriented developments (TODs) in California. The model is based on data from a survey of randomly selected households and workers within a 0.4 mile radius of selected rail stops in San Diego and the San Francisco Bay Area. The survey consisted of a telephone questionnaire and 24-hour activity and travel diaries. It included not only those living in TODs, but also those living in the greater metropolitan area in which the TODs were located, providing for better "control" than census data. The built environment characteristics included in the model were as follows: (1) built form density (structural density of developed land), (2) activity density (mix of uses), and (3) network load density (number of local users per unit of network capacity).

Combined home and work transit proximity demonstrated the strongest correlation with transit commuting; however, the built environment variables most strongly correlated with travel decisions were those that reduce the convenience of auto use. The important consideration is not so much that these variables increase the convenience of non-motorized travel, but that they typically decrease the convenience of motorized travel. Thus, TODs that accommodate the automobile through increased capacity do not tend to produce the desired effect of TODs on travel.

The residential self-selection problem is explored as well. In order to incorporate the potential for residential self-selection into the model, respondents were asked to describe what factors were considered when choosing their current neighborhood, instead of describing their travel preferences (which could be influenced by current travel patterns). Based on statistical tests conducted on survey data, the residential self-selection problem exists, but is not necessarily a strong indicator of travel behavior.

One important policy implication of this study, as discussed previously, is the fact that changes made to the built environment in order to make alternative travel modes more convenient must also make auto use less convenient (i.e. avoid improving road capacity and parking provisions). The second critical policy implication is that TODs should be conceived within the context of a regional scale rather than a local scale, as the large-scale built environment has a substantial impact on travel behavior.

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- **Ewing, R., Bartholomew, K., Winkelman, S., Walters, J., & Chen, D. (2007). **Growing Cooler: Evidence on Urban Development and Climate Change.** Washington D.C.: Urban Land Institute.

Growing Cooler examines the relationship between the built environment, transportation, and greenhouse gas (GHG) emissions. The relationship between smart growth type land use patterns and travel is discussed, as well as the potential for the general public to embrace smart growth strategies. A comprehensive review and analysis of the literature regarding the relationship between land use and travel patterns is conducted. The EPA's Smart Growth Index is presented, which defined sprawl as being composed of four factors (density, mix, centeredness, and street accessibility), and demonstrated that as sprawl decreases, average vehicle ownership and daily VMT per capita decrease, though the density factor has the strongest and most significant relationship to travel. In order to quantify the effects of density on congestion, data from a study examining the relationship between density and congestion were used by the authors to develop an elasticity of congestion with respect to density of 0.14, indicating that density only exacerbates congestion mildly. Elasticities comparing the initial three "Ds" (density, diversity, and design) to VMT and vehicle trips are provided (taken from Ewing and Cervero 2001). The effects of site location on the VMT of project-scale development are examined, and it is found that VMT reductions between 30 and 60 percent are typical of infill locations, when compared to Greenfield development. Overall, the evidence on the built environment and driving indicates compact development can reduce the need to drive by 20 to 40 percent relative to sprawl.

- ******Ewing R, & Cervero R, (2010). **"Travel and the Built Environment: A Meta-Analysis"** *Journal of the American Planning Association,* Vol. 76, No. 3, pp. 265 – 294.

The study begins by noting that both local governments and states are turning to land planning and urban design for help in reducing automobile use and related social and environmental costs. The effects of such strategies on travel demand have not been generalized in recent years from the multitude of available studies. To address this, the authors conducted a meta-analysis of the built environment-travel literature existing at the end of 2009 in order to draw generalizable conclusions for practice. The authors aimed to quantify effect sizes, update earlier work, include additional outcome measures, and address the methodological issue of self-selection. Elasticities were collected and in some cases computed for individual studies and pooled them to produce weighted averages.

<u>Key results:</u> Travel variables are generally inelastic with respect to change in measures of the built environment. Of the environmental variables considered here, none has a weighted average travel elasticity of absolute magnitude greater than 0.39, and most are much less. Still, the combined effect of several such variables on travel could be quite large. Consistent with prior work, the authors find that vehicle miles traveled (VMT) is most strongly related to measures of accessibility to destinations and secondarily to street network design variables. Walking is most strongly related to measures of land use

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diversity, intersection density, and the number of destinations within walking distance. Bus and train use are equally related to proximity to transit and street network design variables, with land use diversity a secondary factor. Surprisingly, the authors find population and job densities to be only weakly associated with travel behavior once these other variables are controlled.

The elasticities derived in this meta-analysis may be used to adjust outputs of travel or activity models that are otherwise insensitive to variation in the built environment, or be used in sketch planning applications ranging from climate action plans to health impact assessments. However, because sample sizes are small, and very few studies control for residential preferences and attitudes, it cannot be said that planners should generalize broadly from our results. While these elasticities are as accurate as currently possible, they should be understood to contain unknown error and have unknown confidence intervals. They provide a base, and as more built-environment/travel studies appear in the planning literature, these elasticities should be updated and refined.

- ******Ewing, R., & Cervero, R. (2001). **Travel and the Built Environment: A Synthesis.** *Transportation Research Record, 1780,* 87-114.

This paper summarizes the majority of recent (as of 2001) studies examining the potential to influence travel behavior through land use changes. Elasticities of VMT and vehicle trips with respect to the three Ds (density, diversity, and design) as well as regional accessibility are provided. General findings regarding household VMT include the fact that trip frequency (regardless of mode) is more dependent on sociodemographic characteristics than on land use variables, whereas trip length is more dependent on land use variables, and mode choice is dependent on both land use and sociodemographic variables. The direct relationship between density and travel is uncertain (i.e. other variables associated with density could be the true cause of observed changes in travel patterns). The evidence regarding the relationship between vehicular travel and transportation networks (e.g. grid patterns versus arterials) is considered inconclusive. The elasticities provided by this study are small, but significant, and could have considerable impacts if additive effects are taken into account.

- Ewing, R., Dumbaugh, E., & Brown, M. (2001). **Internalizing Travel by Mixing Land Uses: Study of Master-Planned Communities in South Florida.** *Transportation Research Record, 1780,* 115-120.

This study seeks to model the effects of land use mix on internal trip rates using 20 mixed use master-planned communities in south Florida. Prior to this, no study had modeled the interaction of such variables. The authors discuss the problems posed by lack of research on internal capture rates of mixed use developments, and state that "...traffic impact studies for mixed use developments are little more than exercise in speculation." Internal capture rates (i.e. trips with both trip ends within the community) were found to range from 0 to 57 percent. Land use measures examined were community size (population +

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jobs), density (size / area), entropy (level of land use mix within the development), balance (the development's jobs-housing ratio as compared to that of the county as a whole), and accessibility. After controlling for size and regional accessibility in the model, land use mix and density were not found to be significant determinants of internal capture rates. This could be due to a variety of sampling errors, or issues of construct validity in the density and land use variables. For example, the density variable included all land area in its denominator, including land unable to be developed. Further, construct validity problems in the land use mix and balance measures may arise due to the fact that many of the businesses included in the commercial category meant to serve larger regional markets (e.g. furniture stores, automobile dealers, etc.). The variable found to be most strongly correlated to internal trip rates in this model was development size, with regional accessibility following as the second most strongly correlated variable (a negative correlation). The authors conclude with a discussion of the need for further empirical research on internal capture rates for such developments.

- **Ewing, R., et al. (2009). **Traffic Generated by Mixed-Use Developments – A Six Region Study Using Consistent Built Environmental Measures.** Transportation Research Board, 88th Annual Meeting. http://www.reconnectingamerica.org/public/show/trafficmixedusedevelopments2009

This study aims to measure the traffic impacts of multi-use developments using a variety of innovative methods. Six regional household travel databases of multi-use developments were chosen for analysis. All trips were able to be classified by purpose and mode, socioeconomic characteristics were controlled for, and data were linked to built environment databases. A total of 35,877 trip ends were generated by the multi-use developments, 29% of which were either internal trips, or non-motorized or transit trips, detracting from the total amount of external vehicle trips generated by these developments. Elasticities are developed to quantify the relationships between a variety of land use and socio-demographic variables and internal trip capture rates, the likelihood of walking or taking transit on external trips, and trip distances for external automobile trips. Overall, variables found to contribute to a reduction in automobile travel include: (1) total and relative amounts of on-site population and employment, (2) site density, (3) size of households and auto ownership characteristics, (4) level of employment within walking distance of the site, (5) pedestrian-"friendliness" of the site, and (6) level of transit provision and access to employment via transit.

- Handy, S. (2004). **Critical Assessment of the Literature on the Relationships among Transportation, Land Use, and Physical Activity.** Department of Environmental Science and Policy, University of California, Davis. Prepared for the Committee on Physical Activity, Health, Transportation, and Land Use, July. http://onlinepubs.trb.org/onlinepubs/archive/downloads/sr282papers/sr282Handy.pdf

This report provides a discussion and review of the empirical evidence regarding the interaction of the built environment and physical activity (often times associated with non-motorized travel). A variety of travel behavior and built environment theories are discussed, most of which shed light on the fact that the

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relationship between the built environment and travel behavior is complex. Studies examining the relationship between the built environment and active travel are explored. Dependent variables examined in these studies included walk trips, non-motorized trips (i.e. walk and bike trips), and non-automobile trips (including transit). Built environment characteristics (i.e. independent variables) included in the studies are population and employment density, land use mix, transportation system measures, measures of accessibility, design measures, and neighborhood type. Control variables consisted of sociodemographic characteristics typically included in regional travel surveys.

Many studies found that population and density measures are significantly positively correlated with non-motorized travel modes. The findings across studies of effects of transportation system measures on active travel were somewhat inconsistent. The variable capturing the distance to destinations generally demonstrated a negative correlation with walking trips, as expected, while other measures of accessibility tended to demonstrate positive correlation with non-motorized trips. Design variables were shown to be statistically insignificant, which could simply serve as an indicator that the variables typically used to measure design are insufficient. The studies that focused on neighborhood type as opposed to various built environment variables tended to demonstrate higher levels of non-motorized trips in traditional or walkable neighborhoods, than in suburban or auto-oriented neighborhoods.

Next, physical activity studies are explored, falling into two categories: (1) correlative studies, and (2) intervention studies. The former identifies relationships between a dependent variable and a variety of independent variables at one point in time, while the latter surveys participants before and after an intervention, and results are compared to a control group in order to determine the effect of the intervention. Many of the correlative studies relied on subjective reported measures of the built environment and mode choice, while a few used more objective measures of the built environment to supplement or replace the reported measures. Measures of physical activity in these studies fell into the categories of walking, other physical activity, and total physical activity. Neighborhood characteristics used to measure the built environment for these studies were different from those in the travel behavior literature. Transportation, design, and safety characteristics were the most used measures of the built environment in the physical activity literature. Overall, it was found that measures of accessibility demonstrate a positive impact on total physical activity, while perceived neighborhood aesthetics, and objective neighborhood characteristics demonstrated strong positive associations with walking.

Although various methodologies were used in these studies, the travel behavior and physical activity studies produced consistent results, indicating that a strong association exists between the built environment and physical activity. However, some ambiguity is present regarding which specific features of the built environment influence physical activity. Though density and neighborhood type were found in some studies to have a strong impact on active travel, more exploration is needed to determine the specific qualities of these variables that impact travel behavior as measures of these variables were inconsistent across studies. On the other hand, accessibility is one variable that, regardless of how it is measured, seems to have a strong influence on physical activity.

Finally, the question of causality versus correlation is raised, and the self-selection problem is discussed. The built environment's interaction with residential self-selection can be conceptualized in a variety ways. One with a propensity toward active travel modes can either be encouraged or inhibited depending on neighborhood characteristics, or the neighborhood characteristics of one with a low preference for active travel modes can reinforce this low preference, or encourage one to change preferences. Various cross-sectional (correlative) studies have indicated that residential self-selection does play a role in travel behavior, though the author discusses the potential of intervention studies to improve understanding of residential self-selection.

Overall, the author finds that further research is needed in order to sort out the degree to which different aspects of the built environments can have a causal effect on physical activity. However, the author concludes that the lack of definitive evidence should not serve as a deterrent to changing the way our communities are designed. Based on existing research, a causal link between the built environment and physical activity is certainly a possibility. Further, other positive outcomes are associated with making neighborhoods less auto-oriented, and minimal risk and cost is associated with doing so.

- **Handy, S., Cao, and Mokhtarian, P. (2005). **Correlation or Causality between the Built Environment and Travel Behavior? Evidence from Northern California.** Transportation Research Part D 10, 427-444. http://www.dot.ca.gov/researchconn/past_speakers/DrHandy/trd_paper.pdf

This study seeks to move beyond establishing a correlation between built environment characteristics (e.g. density, land use mix, transit accessibility, pedestrian friendliness, etc.) and travel choices by exploring a causal relationship between the two. In other words, this study aims to explore whether neighborhood design affects travel behavior, or if instead travel preferences play a role in determining neighborhood choice. In order to do this, a survey was conducted comparing those who had recently switched neighborhood types (the “treatment” group) to those who had not recently moved (the “control” group). Reported vehicle miles driven were used as the dependent variable. Independent, or explanatory, variables included: reported neighborhood characteristics and neighborhood preferences, objective measures of accessibility, travel attitudes, and sociodemographics. Based on a cross-sectional analysis of reported vehicle miles driven, it was found that residential self-selection plays a significant role in the observed correlations between the built environment and travel behavior. Based on the quasi-longitudinal analysis of the change in travel behavior after a move, or after one year of staying in the same neighborhood (controlling for attitudes toward different modes of travel), it was found that changes in the built environment do have an impact on vehicle miles driven. Increased accessibility was the variable that had

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** Study is relevant to integrated land use and transportation analysis and scenario planning.

the greatest negative impact on driving. These findings serve to substantiate the conclusions of previous cross-sectional studies that found a direct relationship between the built environment and travel behavior.

- **Holtzclaw, J., Clear, R., Dittmar, H., Goldstein, D., and Hass, P. (2002). **Location Efficiency: Neighborhood and Socio-Economic Characteristics Determine Auto Ownership and Use – Studies in San Francisco, Los Angeles and Chicago.** *Transportation Planning and Technology*, Vol. 25, pp. 1-27.

This study, sponsored by the Natural Resources Defense Council (NRDC), the Center for Neighborhood Technology (CNT) in Chicago, and the Surface Transportation Policy Project in Washington, DC, includes every neighborhood in the San Francisco, LA and Chicago areas. The zones analyzed are the Chicago Area Transportation Study's 316 Dram-Empal model zones covering the Chicago metropolitan area, the Southern California Association of Governments' 1700 Travel Analysis Zones covering the Los Angeles metropolitan area and the Metropolitan Transportation Commission's 1099 Travel Analysis Zones in the San Francisco metropolitan area.

The dependent variables estimated are vehicles available per household and vehicle miles traveled (VMT). Average vehicle availability for each zone is from the 1990 U.S. Census. VMT per vehicle is derived from odometer readings recorded when owners take their vehicles in for emission systems inspections (smog checks) in California and Illinois. Average VMT per household is calculated as the VMT per vehicle times the number of vehicles per household for each zone. The dependent variables were tested against a wide range of potential explanatory variables, including the most important socio-economic factors of household income and household size. Locational variables tested were: density, transit service and access to jobs by transit, availability of local shopping, pedestrian and bicycle friendliness, and proximity to jobs.

The authors predict a household's VMT as a function of home-zone density, transit service and access to jobs by transit, availability of local shopping pedestrian and bicycle "friendliness"; that is, the "attractiveness" of these options as compared to driving, and proximity to jobs. The elasticities for vehicle ownership with respect to density for Chicago, Los Angeles, and San Francisco were -0.33, -0.32, and -0.35. Elasticities for VMT with respect to density were -0.350, -0.4, and -0.43.

- *Kimley Horn & Associates, with EPS and the Association of Bay Area Governments, for Caltrans (2008). **Trip-Generation Rates for Urban Infill Land Uses in California (Phase 1).** http://www.dot.ca.gov/newtech/researchreports/reports/2008/ca_infill_trip_rates-phase_1_final_report_appendices_4-24-08.pdf

The purpose of this study was to provide information regarding the travel characteristics of urban infill development in California. Specifically, the study aimed to: develop a methodology for infill trip generation data collection and analysis; develop trip generation rates for urban infill developments in California; and make these rates available for use in a database that can serve to supplement ITE *Trip Generation* for estimating trip generation rates for infill developments in California. Ultimately, the research team's goal

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was to incorporate data collected into future relevant ITE publications. Land uses examined by this study include commercial and office developments, high density housing and mixed-use and transit-oriented developments. Sites were selected in metropolitan areas based on multi-modal travel options, with the goal of providing a representative sample of different urban areas around the state of California. Methods for collecting data included manual door counts as well as intercept surveys.

Representative site selection was relatively easy compared to obtaining permission to survey the sites, which was the most challenging aspect of the study as of the completion of phase 1. The most effective approach to gaining permission to survey was found to be soliciting permission from those developers or organizations that had prior relationships with members of the research team, or soliciting permission/recognition from larger groups or organizations that represent or are affiliated with multiple developers (e.g. American Planning Association, local Chambers of Commerce, etc.). In addition to counts and intercept surveys, data were collected regarding independent site variables (e.g. building size, number of employees, etc.), and population (i.e. the number of people accessing a site during the study period).

Various methodologies were explored for empirically measuring as well as estimating daily trip generation rates on site. The most viable methodology was determined to be peak-period counts and intercept surveys to estimate daily trip generation rates. Three pilot studies were conducted at infill sites in Oakland and San Francisco to test this methodology. Following these three pilot studies, ten other sites were identified as appropriate for an expanded pilot study. These sites, in the cities of Berkeley, San Diego, and Los Angeles, were mostly residential, though a few commercial/business land uses were included. Based on this small sample, on average residential sites had lower trip rates than ITE estimates. All non-residential sites surveyed, aside from a supermarket in San Diego, demonstrated lower trip rates than the ITE estimates as well. Overall, this report was very informative regarding optimal data collection techniques and methodologies in order to calculate trip generation rates for urban sites.

- *Kimley Horn & Associates, with Economic & Planning Systems and Gene Bregman & Associates, for Caltrans (2009). **Trip-Generation Rates for Urban Infill Land Uses in California (Phase 2).** http://www.dot.ca.gov/research/researchreports/reports/2009/final_summary_report-calif._infill_trip-generation_rates_study_july_2009.pdf

This is second phase of this project, and provides an overview of the method used for site selection and data collection described in the Phase 1 report. Ten land use types were chosen for data collection to estimate trip generation rates for urban infill developments: high-rise apartment, mid-rise apartment, mid-rise residential condominium/townhouse, high-rise residential condominium/townhouse, hotel, general office building, shopping center/specialty retail, and pharmacy/drug store without drive-through window, quality (sit-down) restaurant, and fast-food restaurant without drive-through window. Based on the sample consisting of 25 sites surveyed during both phase 1 and phase 2, observed trips were lower (by 26% to 40%)

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during peak periods than the ITE trip rates would indicate for all land uses, except: a mid-rise apartment complex in Pasadena, a mid-rise condominium/townhouse site in San Diego, a chain clothing store in San Francisco, and a supermarket in San Diego.

Ultimately, the report concluded that a larger database is needed in order to adequately compare trip generation rates in urban infill developments to those provided by ITE *Trip Generation.* Recommendations for future research include: trip rate validations, development of correlations between specific site characteristics and trip generation rates, and exploring incentives for developers to allow site surveys.

- **Kockelman, Kara, Matt Bomberg, Melissa Thompson, and Charlotte Whitehead (2008) **GHG Emissions Control Options: Opportunities for Conservation.** Report Commissioned by the National Academy of Sciences for the Committee for the Study on the Relationships among Development Patterns, VMT, and Energy Conservation.

This paper summarizes the magnitude of greenhouse gas (GHG) emissions reductions one can expect from a variety of widely discussed (and often debated) policies and design strategies. These include vehicle technologies, transport modes, fuel types, appliances, home and building design, and land use patterns. Through a detailed review of existing literature, the work strives to identify the greatest opportunities for carbon savings, reflecting, to some extent, cost implications and behavioral shifts needed. Greatest near-term gains mostly emerge in relatively conventional vehicle design shifts, dietary changes, and home weathering. In the medium term, significant energy and emissions savings are likely to come from fuel economy regulations approximating those abroad, appliance upgrades, plug-in hybrid purchases, home heating and cooling practices, and power generation processes. In the longer term, building design practices, carbon capture and sequestration, and a shift towards cellulosic and other fuels appear promising. Ultimately, however, to achieve 50- to 80-percent reductions in GHG emissions, relative to current or past levels, major behavioral shifts are probably needed, motivated by significant fuel economy legislation, energy taxes, household-level carbon budgets, and cooperative behavior in the interest of the global community.

With respect to urban form factors the authors note that these do not appear to be as influential as demographic and economic variables, but are more subject to public policy and regulation. The authors cite Bento et al. (2005) who found that road network and distribution of population throughout the city were the greatest urban form determinants of VMT, while VMT and commute mode were most dependent upon the pattern of residential land use and distribution of employment. The authors note that the 2001 National Household Travel Survey results suggest that VMT per vehicle is rather stable across households owning one to three vehicles. Thus, reducing vehicle ownership may be an important means to reducing VMT. Tables 22, 23, and 24 summarize elasticities of demand for vehicle with respect to parking, density and urban design variables.

- Lin, J.J. & Yang, A.T. (2009). **Structural Analysis of How Urban Form Impacts Travel Demand: Evidence from Taipei.** *Urban Studies, 46(9),* 1951-1967.

This study analyzes the relationship between the built environment and travel demand in Tapei, Taiwan. The complex relationship between land use variables and travel is discussed, and structural equation modeling is used to clarify this complex relationship. Urban form variables used in the model include density (residential density, building density, and employment density), diversity (land use type mix, housing-job mix, housing-retail mix, retail-job mix, and land use entropy), and design (road density, grid network, and sidewalk density). Travel demand variables included in the model were trip generation and private mode split. Finally, control factors in the model include transit service, private mode facility (e.g. access to automobiles, and parking space density), and socioeconomic variables. Data were obtained at the traffic analysis zone level for the model from the Tapei City Bureau of Transport, and other Tapei City Government Agencies. Based on the model, it was found that density is positively related to trip generation and negatively related to private mode split. Land use mix is negatively associated with trip generation, and indirectly positively related to private mode split. Pedestrian friendly design was found to reduce private mode split. Though most of these findings support findings from studies conducted in the United States, national differences in previous land use patterns may serve to explain any differences.

- Lund, H., Willson, R., and Cervero, R. (2006). **A Re-evaluation of Travel Behavior in California TODs.** *Journal of Architectural and Planning Research*, Vol. 23, No. 3, pp. 247-263.

Building on the authors' prior work (Lund, Cervero & Wilson, 2004) , this reevaluation of survey data from residents living near rail station notes that transit-oriented development (TOD) clearly, but unevenly, encourages walking to transit as well as transit use California region's with rail transit. Survey sites were all located in non-Central Business District (CBD) locations, within walking distance of a transit station with rail service headways of 15 minutes or less, and were intentionally developed as TODs. Surveys were conducted along each of California's major urban rail systems, including: the San Diego Trolley, San Diego Coaster, Los Angeles Blue and Red Lines, Los Angeles Metrolink commuter rail, San Jose VTA light rail, Caltrain commuter rail, the Bay Area Rapid Transit District (BART), and Sacramento Light Rail.

The 2004 study found that residents living near transit stations were around five times more likely to commute by transit as the average resident worker in the same city, while office workers at work sites near transit were three and a half times as likely to use transit as average workers in the same cities. The reevaluation suggests that TOD can reduce per capita automobile travel, but this is only likely to be realized when transit systems reach sufficient coverage and efficiency to provide an attractive alternative to automobile travel.

- Saelens, B., & Handy, S. (2008). **Built Environment Correlates of Walking: A Review.** *Medicine and Science in Sports and Exercise, Vol 40, No 7S,* S550-S566.

This paper reviews the literature between 2002 and 2006 on the relationship between specific characteristics of the built environment and walking for transportation and recreation. Specifically, this report synthesizes reviews of research, and original research conducted in both the transportation and public health fields regarding the interaction between the built environments and walking. Many reviews found that accessibility, measured as distance to destinations, is associated with walking. Aesthetics were found to be another important indicator of walking in multiple reviews, though factors used to measure aesthetics varied widely across studies. Street connectivity also played an important role as it is closely related to accessibility. Safety attributes were also positively correlated with walking. Most reviews discussed a need for more objective measures of environmental variables, and improved measures of walking, though the authors do mention that recent studies have incorporated more objective measures of the built environment than their predecessors.

The more recent studies found consistent positive relationships between walking for transportation and density, distance to nonresidential destinations, and land use mix. However, the question of causality still poses a problem for those wishing to understand more about the relationship between the built environment and active travel (in this case, walking). The following policies are specifically recommended to shape the built environment, influence aesthetic qualities, and encourage walking: designation of mixed use zoning districts, infill development and redevelopment programs, designation of historic districts, greyfield redevelopment, traffic calming programs, street connectivity ordinances, and requiring developers to provide amenities that make communities more livable.

- ******San Francisco Bay Area Metropolitan Transportation Commission (2006). **Characteristics of Rail and Ferry Station Area Residents in the San Francisco Bay Area.** Oakland, CA. http://www.mtc.ca.gov/planning/smart_growth/stars/

This study was undertaken to characterize the demographic and travel characteristics of station area residents — individuals living within close proximity to stops and/or ferry terminals in the region — compared to residents living elsewhere in the region. Transit Oriented Development (TOD) was defined as development within a one-half-mile *walking* distance (taking account of barriers and walkway circuity) of a rail or ferry terminal. Demographic and travel data were from MTC's 2000 Bay Area Travel Survey. This survey compiled travel and demographic data for some 35,000 individuals aged 16 years and above residing in nearly 15,000 Bay Area households.

Analysis of Bay Area survey results revealed that people living within a half-mile walking distance of a rail transit or ferry station are four times more likely to use transit than those living farther away than a half-mile. The data show that people who live and/or work within a half-mile of major transit or ferry stations

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averaged 42% of their daily trips by transit, walking or biking. Nearly a third of these do not own a vehicle. By comparison, people who live and/or work within a half-mile walking distance of ferry or major transit stations generate about one-half the VMT of suburban and rural residents in the SF Bay Area.

The study also found that the vehicle mode share of residents within a half mile of a rail station or ferry terminal is 28 percent lower than for the region as a whole. The same data also indicate that the transit mode share of residents increased by 14 percent in such areas. This suggests that about half of the reduction in vehicle trips observed for station/terminal area residents may be attributed to the substitution of transit for private vehicle trips.

- **Shay, E. & Khattak, A. (2007). **Autos, Trips, and Neighborhood Type: Comparing Environmental Measures.** Transportation Research Board, 86th Annual Meeting. http://www.eng.odu.edu/transportation/khattak/New_Clusters_TRB_2007.pdf

This paper examines the relationship between neighborhood design, socio-demographic characteristics, auto ownership, and trip generation. The authors discuss "neo-traditional" development as typically associated with lower auto ownership rates, higher pedestrian/transit trips, and lower VMT, while offering the caveat that this may be due to self-selection. The paper describes a model developed by the authors using survey data from the Charlotte, NC region. In the process of developing this model, the authors used 34 direct measures of the built environment, then derived factors out of these direct measures using factor analysis, and finally performed cluster analysis to group together similar neighborhoods in terms of factors. These factors and clusters were then compared with auto ownership and trip generation. According to the authors, examination of the factors yielded more interesting results than that of the clusters. Factors derived from factor analysis were walkability, accessibility, agglomeration, property value, and level of industrial land use. Based on regression analysis, accessibility was the one land-use factor that was highly correlated with auto ownership (indicating a negative correlation between the two), while both accessibility and walkability were positively correlated with overall trips. The coefficients derived from regression analysis may be of interest in the development of a new trip generation model. However, because this analysis is based on data from North Carolina, it is less applicable in California.

- **Transportation Research Board Special Report 298. (2009). **Driving and the Built Environment: The Effects of Compact Development on Motorized Travel, Energy Use, and CO_2 Emissions.** Washington, D.C.: Transportation Research Board.

This study aimed to establish a scientific basis for analysis of the relationships between development patterns, vehicle miles traveled (VMT), energy consumption, and greenhouse gas (GHG) emissions for the purpose of informing policymakers as they adapt to California's Senate Bill 375. This bill requires the state's metropolitan planning organizations to provide incentives for local jurisdictions to incorporate more compact development and transportation alternatives into their future plans for the purpose of reducing

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GHG emissions by assigned target amounts. A decline in metropolitan density due to suburbanization and its implications for transit use are discussed. The generally accepted density threshold for a successful transit system is noted to be 7 to 15 dwelling units per residential acre, and the typical ½ mile catchment area for transit stations is mentioned. The importance of accounting for the many variables often associated with both density and VMT is discussed. These variables include accessibility, land use mix, development design, connectivity of street network, and demand management policies. Explanations for variability in the findings across studies are explored, including the use of disaggregate versus aggregate data, cross-sectional versus longitudinal studies, the self-selection problem and the uncertainties associated with causality, the measurement and scale of the different variables, and the generalizability of results.

The researchers found that developing at higher population and employment density is likely to reduce VMT rates. Further, evidence from the literature suggests that a doubling of residential density across a metropolitan area may reduce household VMT by 5 percent to 12 percent, and up to 25 percent if combined with other land use practices and policies thought to reduce VMT (e.g. higher employment density, mixed land uses, transit improvements, etc.). Particularly, the effects of land use strategies and transit availability together were found to be considerably greater than those of either one individually.

Chapter four introduces strategies to overcome impediments to compact development. These strategies include a focus on building compact new housing developments, relaxing zoning restrictions to enable more compact and mixed use developments, creating incentives for developers and lenders to invest in compact and mixed use development, and implementing integrated street design and reduced parking requirements in such developments.

Finally, previous national estimates are examined to determine the potential impact of compact development patterns on VMT, and the results of the authors' own development scenarios are presented. One study estimated that shifting growth by 2025 from sprawl to a controlled growth scenario (which moves 11 percent of new housing, and 6 percent of jobs to more urbanized areas) would reduce person miles traveled by 4 percent overall. Another study estimated VMT per capita to be 30 percent less in compact developments than in their conventional counterparts. Results of a scenario study conducted by the authors indicate that a doubling of density in 25 percent of new residential development could reduce VMT by 12 percent in both 2030 and 2050, while a doubling of density in 75 percent of new residential development could reduce VMT by 25 percent in the same time frame. Further benefits and costs of compact development are explored. Noted benefits include improved energy efficiency of buildings, land conservation, and increased physical activity. One potential cost is that of increased necessity for transit investment. Overall, the authors recommend to policymakers that policies in support of more compact, mixed use development should be encouraged.

- **Wallace, B., Mannering, F., & Rutherford, G.S. (1999). **Evaluating Effects of Transportation Demand Management Strategies on Trip Generation by Using Poisson and Negative Binomial Regression.** *Transportation Research Record, 1682,* 70-77.

This paper examines how various travel demand management (TDM) strategies can be incorporated into trip generation models for planning purposes. Using multi-modal travel survey data from the Puget Sound Transportation Panel (PSTP), the authors use Poisson regression techniques to analyze the effects of five TDM strategies on home-based work trip generation. The five strategies examined are as follows: (1) telecommunications strategies (i.e. telecommuting), (2) alternative work schedules (i.e. compressed work weeks), (3) on-site amenities at work, (4) pricing strategies (i.e. parking charges), and (5) land use strategies (i.e. urban center vs. non-urban, and distance from home to work). The results from the regression analysis are provided in the paper, including correlation coefficients for each of the variables examined. Variables of interest to the Smart Growth Trip Generation Rates spreadsheet effort include the two land-use variables of urban center vs. non-urban, and distance from home to work. Distance from home to work is negatively correlated with home-based work trips, while living in an urban center is much more highly (and positively) correlated with home-based work trips. The authors speculate that this may be due to trip-chaining: those living in urban centers (which tend to incorporate a mix of land uses, higher density, etc.) are less likely to feel the need to trip-chain between work and home, as making personal trips independent from their commute is presumably not as difficult for these people as it is for those living outside urban areas. This could also provide an explanation for the negative correlation between distance from home to work and home-based work trips: if trip-chaining occurs on the way to or from work, this trip is no longer counted as a home-based work trip. Finally, the authors discuss the differences between land-use strategies and other TDM strategies, and it is determined that perhaps instead of treating land-use strategies as variables within a trip generation model, separate trip generation models should be created for distinct land-use types.

- ******Zhang, M. (2005). **Intercity Variations in the Relationship Between Urban Form and Automobile Dependence: Disaggregate Analyses of Boston, Massachusetts; Portland, Oregon; and Houston, Texas.** *Transportation Research Record, 1902,* 55-62.

This study focuses on improving understanding of the relationship between urban form, access to a variety of travel mode choices, and the shift in mode choice from automobile travel to non-automobile travel. This is done through a modeling of mode availability and mode choice in three distinct cities: Portland, Oregon; Boston, Massachusetts; and Houston, Texas. Trip diary surveys were used as the primary source of data for all three cities. Based on the model, it was found that vehicle ownership and home distance to transit tend to influence whether people consider non-automobile modes feasible, with increased automobile ownership and poor transit service both correlated with high automobile dependence. When socioeconomic and transit supply variables are controlled for, population density was associated with a lower probability of automobile dependence in both Portland and Boston. However, no such association

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was found in Houston. After completion of the modeling phase, the authors estimated disaggregate elasticities of automobile dependence and driving choice with respect to density, transit access, and vehicle ownership. Houston, which is quite automobile dependent, demonstrated the smallest elasticities. The authors speculate that this may indicate that places with established high levels of automobile dependence will have a harder time overcoming this automobile dependence through improvements in density and transit access and decreased vehicle ownership. Overall, the authors found that land use densification and improved access to transit can help to increase travel options and encourage modal shifts from driving to non-driving.

B. Applied Methods

- ******California Department of Transportation (Caltrans). (2010). **Smart Mobility 2010: A Call to Action for the New Decade.** February 2010. http://www.dot.ca.gov/hq/tpp/offices/ocp/smf.html

In this guidebook, "Smart Mobility" is defined as the provision of a safe, efficient, and equitable transportation system that facilitates reductions in auto use and greenhouse gas emissions. Keys to Smart Mobility are the principles of location efficiency, reliable mobility, health and safety, environmental stewardship, social equity, and robust economy. The concept of location efficiency includes coordinating land use and transportation decisions to facilitate multi-modal travel while improving accessibility. Many features that can be categorized under the concept of the "Ds": mixed land uses, high quality urban design, increased density, distribution of public facilities, and quality transit service. Next, reliable mobility emphasizes efficient congestion response, provision of multi-modal options, and avoidance of capacity increases that may induce vehicle travel. Important to the concept of health and safety is the promotion of "active" travel modes (e.g. walking, biking), system optimization to reduce injuries and fatalities, and reduction of public exposure to transportation related pollutants.

Environmental stewardship, from a Smart Mobility perspective, consists of preserving current infrastructure and development, enhancing the natural and built environment through transportation programs that encourage their preservation, and contribution to climate and energy sustainability through improved land use and transportation planning. The concept of social equity is discussed as focusing on efficient access to non-vehicular travel modes, and developing performance measures that evaluate the impacts of land use and transportation decisions on diverse population groups. Finally, a robust economy can be cultivated through Smart Mobility through improved freight operations, minimized transportation costs, and maximized public return on transportation investments through improved project foresight.

Seven "Place Types" are introduced, which are distinguished based on community design and regional accessibility, both of which have been shown to affect travel behavior. Priorities in each of these place

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types are defined for the advancement of Smart Mobility. Priorities in Urban Centers include: provision of efficient multi-modal travel, re-investment in existing roadways, and pricing strategies to optimize roadway and parking capacity.

Priorities in compact communities and compact communities in close proximity to urban centers include: improved transit and enhanced connectivity to foster non-motorized travel modes. Priorities in suburban areas include: increased connectivity to reduce average trip length, improved bicycle and pedestrian infrastructure, and investments to increase the efficiency of existing roadways. Included in the many performance measures proposed to determine the success of Smart Mobility implementation are transit mode share, and pedestrian and bicycle mode share.

- **Cervero, R. (2006). **Alternative Approaches to Modeling the Travel-Demand Impacts of Smart Growth.** *Journal of the American Planning Association*, Vol. 72, No. 3, pp. 285-295.

This study begins by noting that four-step trip-based travel demand forecasting models were not developed to estimate the travel impacts of neighborhood-level smart growth initiatives like transit villages, but rather to guide regional highway and major transit investments. It notes that while progress has been made in enhancing large-scale models to make them more sensitive to local, small-scale elements of smart growth, some analysts have turned to post-processing and direct models to reduce modeling time and cost, and to better capture the travel impacts of neighborhood-scale land use strategies.

This article presents examples of direct or off-line modeling of rail and transit-oriented land uses for greater Charlotte, the San Francisco Bay Area exurbs, and south St. Louis County. These alternative approaches provided a useful platform for scenario testing, and their results revealed that concentrating development near rail stations produced an appreciable ridership bonus. The study deems these alternative models are appropriate as **sketch-planning** supplements to, but not substitutes for, traditional travel models.

- Chang, T. (2005). **Memorandum re: INFORMATION – Level of Service Technical Working Group Update.** San Francisco County Transportation Authority.

This memorandum discusses the Transportation Authority Board's adoption of the Transportation Level of Service (LOS) Methodologies Strategic Analysis Report (SAR), which recommends adjustments to the measurement of transportation impacts as well as the review of transportation impacts under CEQA. Specifically, the SAR recommends that LOS be replaced with vehicle trips generated as an indicator of traffic impact. This ensures that improvements to transit, pedestrian, and bicycle infrastructure are not adversely impacted by unnecessary mitigation fees. In order to determine vehicle trips generated, the methodology outlined in the San Francisco Planning Department's Guidelines for Environmental Review is suggested. Additionally, the SAR recommends that mitigation fees for various projects should be combined in order to fund multi-modal transportation projects to mitigate growth at the system-wide level. The

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methodology mentioned for estimating vehicle trip generation will be examined in more detail as a part of our project's tools search.

- **DKS Associates, the University of California, Irvine & Santa Barbara, and Utah State University (2007) **Assessment of Local Models and Tools for Analyzing Smart-Growth Strategies – Final Report** (for Caltrans) http://www.dot.ca.gov/newtech/researchreports/reports/2007/local_models_tools.pdf

Objectives of this project were to: review existing local travel models in California, assess their ability to analyze the effects of smart growth strategies on travel behavior, and examine the availability of techniques and tools that can contribute to the overall sensitivity of travel models. More specifically, this paper discusses the extent to which the "4D" elasticities (density, diversity, design, and destinations) contribute to the sensitivity of travel models to smart growth strategies. The many limitations of the Urban Transportation Modeling System (UTMS), or the "traditional four-step travel demand model" as it is commonly known, are discussed regarding sensitivity to smart growth. Methods to overcome these limitations are introduced, which can be divided into four categories: (1) post-processor to UTMS for application of smart growth trip and VMT elasticities, (2) stand-alone tools for aggregate application of smart growth trip and VMT elasticities, (3) enhancement of UTMS models, and (4) integrated land-use, economic, and transportation models.

Next, the 4D elasticities are introduced, which measure the interactions between the characteristics of built environments, vehicle trips, and VMT. Included in the discussion of these elasticities is an overview of "Do's and Don'ts" provided by Fehr and Peers Consultants, which outline conditions for optimal use of 4D elasticities. Among other restrictions, they "indicate that the 4D elasticities were not appropriate for use in analysis of small-scale developments (below 200 acres) and/or in CEQA analyses. An overview of a few existing tools that utilize these elasticities includes: PLACE3S/I-PLACE3S, INDEX (both of which are "stand-alone tools for aggregate application of smart growth trip and VMT elasticities"), and URBEMIS. PLACE3S is a software tool for assessing and comparing planning scenarios. I-PLACE3S is an internet-based version of PLACE3S that the Sacramento Area Council of Governments (SACOG) developed and used in its regional Blueprint planning program. INDEX is a GIS-based sketch-planning tool developed by Criterion Engineering in Portland, Oregon that incorporates a 5th D (distance to heavy rail transit stations). Also discussed is URBEMIS, a primarily air-quality impact assessment tool that estimates multi-modal trip generation, VMT, and related air quality impacts of land uses up to 50 acres in size.

Next, the state of the practice of travel modeling in California is discussed. Though many smaller metropolitan planning organizations (MPOs) and regional transportation planning agencies (RTPAs) rely on travel demand models that lack sensitivity to smart growth, some of the larger MPOs and local jurisdictions have improved their models including: the San Francisco Transportation Authority, SACOG, MTC, SLOCOG, Contra Costa County, Humboldt County, Fresno and Madera Councils of Government, the City and the

County of Sacramento, among others. To expand upon this analysis, case studies were presented of six cities in California regarding their plans to improve the sensitivity of their travel models, including four cities that use multi-modal travel models: (1) San Diego, whose model tests smart growth developments and transit focused areas, (2) San Jose, whose model incorporates certain socio-demographic variables (auto ownership and income), (3) Fresno, and (4) West Sacramento, both of latter two cities' models use a 4D post-processor. Other jurisdictions identified in the case studies were: the City of Irvine, which plans to incorporate the 4Ds in its travel model; and the City of San Luis Obispo, which has tested the potential use of 4Ds elasticities for planning.

- Ercolano, J.M., Olson, J.S., & Spring, D.M. (1997). **Sketch-Plan Method for Estimating Pedestrian Traffic for Central Business Districts and Suburban Growth Corridors.** *Transportation Research Record, 1578,* 38-47.

This paper analyzes a method to determine future peak-hour pedestrian-trip volumes in central business districts and suburban growth corridors. The method consists of three steps: 1) Estimating sources of pedestrian trips (i.e. determining potential sources of pedestrian trips from motor vehicle, transit, and walk and bike-only trips), 2) Estimating average peak pedestrian-per-hour (pph) trip rates per person (i.e. estimating peak pph using vehicles-per-hour (vph) and other mode data), and 3) Determining pph trip distribution and assignment. The second step is of particular interest for this analysis. These steps were tested using two different methodologies for the estimation of peak pph trip rates in the town of Plattsburgh, NY. The first of these methodologies is a mode-based estimation for pedestrian trip generation rates. In this methodology, pedestrian trips are divided into three types: 1) Car-walk linked person-trips (CWL trips – estimated at 90% of total mode share), 2) Walk-only and bike-only person-trips (WBO trips – estimated from census data for the state of NY to be 7%), and 3) Transit-walk linked person-trips (TWL trips – estimated from census data to be 3%). The peak pph for the first type of pedestrian trips (WBO trips) is calculated using the following methodology, taking into account through-trips and vehicle occupancy:

Peak pph = (Peak vph - through-movement trips) = [(vph turning movements) x
(1.5 default average vehicle occupancy) x (5 trips per person) x (20 percent drive-through, etc.)]

The second methodology used to estimate peak pph trip rates is based on land-use. The first step in this methodology was to estimate the on-site trip rate average, which is assumed to equal the local trip rate times 93 m^2. This will be of greater significance in the final step of the methodology. The second step is to adjust this data for various land uses. The adjustment factors are as follows: 0.67 for urban areas with populations up to 50,000, 2) 1.0 for urban areas with populations from 50,000 to 500,000, and 3) 1.33 for urban areas with populations from 500,000 to +1,000,000. Third, a peak-hour adjustment factor was determined based on historical pedestrian-peaking characteristics and variations in peak demand by land use types. This factor was determined to be 1.5 times the average hourly volume for peak hours (to be

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applied to the average trip rate during peak hours). Finally, in order to calculate the total peak pedestrians per hour walk trips as generated by land use, the following formula was used:

Total peak pph (for each TAZ by land-use type) = (total m^2 per TAZ/93 m^2) x (av. trip rate as calculated above)

When these two methods were compared, the mode-based pedestrian trip generation model was found to be 9% less on average than the land-use pedestrian trip generation model. Although this methodology is simple and straightforward, the methodology for deriving the adjustment factors and numbers is not provided.

- Fulton, W. & Aubry, R. (2005) **Utilizing GIS to Help Both Cities and Developers Analyze Infill Development Potential.** Solimar Research Group, Inc. http://www.esri.com/industries/planning/docs/solimar_gis.pdf

This paper outlines the creation of and potential uses for the Infill Analysis Tool created by Solimar Research Group. This tool uses GIS software and Microsoft Excel to analyze which areas within a city would be appropriate for infill development. Since its creation, the tool has been used by housing developers in New York, New Jersey, and California. The tool relies on a combination of parcel-level data (e.g. parcel vector data, assessor attribute data, and zoning data) and block- or district-level data (e.g. census data, employment data, environmental constraints, transportation data, infrastructure capacity and scheduled capital improvements, etc.). In the transportation sector, the tool can be used to identify where infill sites would best be located in order to take advantage of existing transportation infrastructure, as well as to better forecast the environmental impacts of infill policy proposals under CEQA. This is the case as the tool allows policymakers to focus specifically on the parcels eligible for redevelopment under a given policy, instead of assuming all parcels would be eligible. Though no direct examples were provided regarding the ability of the tool to estimate the environmental (or traffic) impacts of infill development, this paper provides an interesting overview of the process used to develop a user-friendly tool using software that is readily available for most practitioners.

- **Johnston, R. (2008) **Review of U.S. and European Regional Modeling Studies of Policies Intended to Reduce Transportation Greenhouse Gas Emissions.** *Institute of Transportation Studies,* University of California, Davis, Research Report UCD-ITS-RR-08-12. http://pubs.its.ucdavis.edu/publication_detail.php?id=1166.

With the enactment of new federal transportation legislation in 2005, State and regional transportation plans and programs are for the first time required to achieve the objectives of the SAFETEA-LU planning process, which focus on enhancing mobility and supporting economic development, while minimizing conventional emissions and greenhouse gas emissions. In 2007, the U.S. Supreme Court held that greenhouse gases are a pollutant and so are covered by the Clean Air Act and, consequently, the USEPA can

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regulate them. California and 13 other states are now attempting to regulate the emissions of greenhouse gases from vehicles.

The results from over 40 long-range regional scenario exercises performed in the U.S. and Europe demonstrate that substantial reductions in vehicle-miles of travel (VMT), fuel use, and emissions of both criteria pollutants and greenhouse gases are possible using transportation pricing policies and investment priorities that have been demonstrated as acceptable and effective in a modest but growing number of metropolitan areas and regions around the world. These studies show that substantial reductions in travel and emissions of pollutants and greenhouse gases are possible (10%-30%, compared to the future base case), but only with combined transportation investment, land use, and travel pricing policies.

- **Matley, T., Goldman, L., & Fineman, B. (2000). **Pedestrian Travel Potential in Northern New Jersey: A Metropolitan Planning Organization's Approach to Identifying Investment Priorities.** *Transportation Research Record, 1705,* 1-8.

This paper outlines the development of a "pedestrian potential index" (PPI) by the New Jersey Transportation Planning Authority (NJTPA). The NJTPA developed this tool in order to determine where increased pedestrian trips may take place if the proper infrastructure were developed. The PPI is based on the relationship between land use mix, density, and urban design, with a strong emphasis on the importance of proximity and connectivity. Census tract level data were used to measure gross employment density, gross population density, and land use mix as indicators of proximity, in addition to street network density as an indicator of connectivity. Employment density and population density were calculated per square mile, using only census information. In order to measure land use mix, an entropy formula was used to determine how evenly land areas in each tract were distributed among different land use types. Finally, street network density was measured in street miles per square mile using GIS and census tract land areas. All of these indicators were verified through a comparison with cities of three distinct land use types (urban, suburban, and rural). A low and high threshold was set for each indicator, and a census tract had to pass three of the four thresholds in order to be considered a "high potential" pedestrian area. Those tracts passing the higher threshold were considered high priority areas for improved pedestrian infrastructure. Though this process does not directly estimate pedestrian trips generated, it is an effective method of using readily available data to produce indicators of walkability at the census tract level.

- *Muldoon, D., & Bloomberg, L. (2008). **Development of Best Practices for Traffic Impact Studies.** Transportation Research Record, 2077, 32-38.

The Oregon Department of Transportation (ODOT) completed a Best Practices for Traffic Impact Studies (TISs) in response to concerns that TISs are typically not as accurate as they could be. As a part of the research for this project, case studies for actual developments were conducted to verify estimated traffic impacts, in addition to a literature review regarding the state of the practice. Based on verification of case

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studies, trip generation estimates tended to overestimate peak-hour trip generation. It was determined that this overestimation is in part due to confusion regarding the proper use of ITE's *Trip Generation.* Cited sources for such errors include improper land use code selection, inadequate assessment of pass-by trip reductions, failure to consider seasonal variations in traffic counts, and lack of multi-modal evaluation. Although this project seems to do little more than advise practitioners to exercise caution when using ITE's *Trip Generation* estimates, it certainly supports arguments in favor of a context-sensitive trip generation tool to for Traffic Impact Studies.

- **Replogle, M. (1993). **Land Use/Transportation Scenario Testing: A Tool for the 1990s.** Transportation Research Board 72nd Annual Meeting.
  http://tmip.fhwa.dot.gov/resources/clearinghouse/docs/landuse/luts/luts.pdf

This paper begins by discussing the need for alternative analysis methods for land use and transportation scenarios. In particular, scenarios that do not favor automobile oriented development are emphasized. The author discusses the inadequacies of standard methods used to determine transportation impact fees for new developments (particularly their insensitivity to urban design factors). Next, advancements in modeling efforts which include more long-range planning scenarios are discussed. Of particular focus are planning efforts that were underway in Montgomery County, Maryland at the time. Montgomery County crafted various planning scenarios incorporating different growth levels and jobs/housing mixes, in addition to different types of growth in transportation infrastructure. These scenarios were tested in particular for their effects on VMT. Ultimately, based on the Montgomery County scenarios, the author concludes that VMT and mode share can be influenced by transportation incentives and enhancements, urban design, and changes in land use patterns that complement transportation investments. Though this paper is somewhat outdated, it serves as an interesting indicator that the issues inherent in current transportation impact analysis methods have been recognized as significant impediments for decades.

- **Rodier, C.J. (2009). **An International Review of the Modeling Evidence on the Effectiveness of Transit, Land Use, and Auto Pricing Strategies.** *Transportation Research Record*, 2132, 1-12.

With an eye toward recent greenhouse gas (GHG) reduction legislation in California, this paper reviews the international modeling literature on land use, transit, and auto pricing policies. Modeling-based studies in California, elsewhere in the US, and in Europe are analyzed to suggest a range of VKT and GHG reduction that regions might achieve if such policies were implemented separately or in combination. To account for the fact the three types of policies examined have different time frames for full implementation and effectiveness (e.g., land use changes take longer to be effective than pricing changes), the author develops order of magnitude estimates for 10-, 20-, 30-,and 40-year time horizons.

The review concludes that land-use-only policy packages can potentially reduce VKT by up to 2% in the 10-year time horizon. The effectiveness of land use strategies may increase by approximately 2 to 3

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percentage points to a higher reduction level at 10-year increments. Land use plus transit scenarios may reduce VKT by 2% to 6% during a 10-year time horizon, and these figures may increase by approximately 2 to 5 percentage points for each future 10-year increment. Combined land use, transit, and pricing policy measures would bring significantly greater reductions in both the shorter- and the longer-term time horizons. The review also concludes that even improved calibrated travel models are likely to underestimate VKT reductions from land use, transit, and pricing policies. Most California models are not yet suited for the policy analysis demands in the era of global climate change.

- Samdahl, D.R. (2009). **Multi-Modal Impact Fees.** *Washington State ITE Newsletter* Vol. 19, No. 8, 9-13. http://www.westernite.org/Sections/washington/newsletters/Samdahl%20multimodal%20impact%20fees.pdf

This article outlines the process used by the cities of Seattle and Portland, OR to assess appropriate multi-modal allocation of revenue generated by traffic impact fees. In order to do this, the cities had to develop methods of determining multi-modal trip generation rates. Seattle's method utilized data from the regional household activity survey in order to determine the typical person trips to vehicle trips ratio. This allowed them to convert ITE's vehicle trip generation rates to person trip generation rates. Then modal split factors from the same survey were used to determine the total person trips per mode. Portland took a similar approach to determine multi-modal trip generation rates. Again, ITE vehicle trip generations rates were converted to person trip generation rates. In this case, two factors were combined to determine person trips from vehicle trips. These factors were (1) average vehicle occupancy for Portland, based on a region-wide traffic count, and (2) a motorized mode share determined for geographic conditions such as those on which the ITE trip generation rates are based (90%). Once person trips were determined from vehicle trips, they were split into modes using 2017 travel forecasting data for Portland.

Additionally, the number of vehicle trips was multiplied by an unspecified trip length adjustment factor. The assumption behind this effort is that a method for assessing multi-modal impact fees will be necessary as urban areas will no longer be able to accommodate further road development and growth of vehicle infrastructure. Thus, the enhancement of multi-modal infrastructure to accommodate increased trip rates associated with new development projects will be a better investment of revenue collected from traffic impact fees. Overall, this paper provides a fairly simple method for deriving multi-modal trip generation estimates from ITE estimates. However, this methodology may not be ideal to incorporate into a tool for widespread use as it relies heavily on local travel data.

- *San Francisco Planning Department. (2002). **Transportation Impact Analysis Guidelines for Environmental Review.** http://www.sf-planning.org/Modules/ShowDocument.aspx?documented=6753

This document introduces guidelines for conducting traffic impact analyses (TIAs) in the City and County of San Francisco. Included in these guidelines are estimates of person-trip generation rates for different land

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use types. The land uses included in these estimates are representative of most of the current developments in San Francisco. If a particular land use is not listed in the document, the planning department encourages the use of the SANDAG tool or ITE's *Trip Generation,* using average auto occupancy to convert vehicle trips to person-trips. The trip generation table provided in this document provides estimates of person-trips generated per square feet, in addition to percentage splits between work and non-work trips for a 24-hour period, as well as the PM peak period. Sources of these estimates include data from the Citywide Travel Behavior Survey, various environmental impact reports (EIRs) including Mission Bay 1990 FEIR, 525 Golden Gate FEIR, and 1000 Van Ness FEIR, as well as ITE *Trip Generation*, 6th edition. Although this trip generation table is simple and user-friendly, the methodology used to estimate the numbers provided in the table is not well documented in this paper.

- **Turner, S., Hottenstein, A., & Shunk, G. (1997). **Bicycle and Pedestrian Travel Demand Forecasting: Literature Review.** Texas Transportation Institute. http://tti.tamu.edu/documents/1723-1.pdf

Researchers from the State of Texas Department of Transportation (DOT) performed a review of the literature regarding current practices in bicycle and pedestrian travel demand forecasting techniques, as a preliminary step in the development of a methodology of forecasting bicycle and pedestrian travel demand in Texas. This review identifies four basic categories of bicycle and pedestrian demand forecasting models: (1) aggregate or simplified trip generation models (using survey data at the zonal level to predict the extent of bicycle and pedestrian travel demand at this level); (2) facility locator or "market travelshed" models, which treat bicycle and pedestrian facilities as trip destinations; (3) sequential stand-alone bicycle and pedestrian demand models similar to current four-step traffic models; and (4) four-step traffic models modified to account for bicycle and pedestrian environments.

Many of the models discussed are not entirely relevant to site-specific trip generation, as they are estimated at the zonal-level (e.g. TAZ, census tract, etc.). One model used bicycle trip generation rates per capita in order to estimate new bicycle trips generated by a bike path in Rhode Island. This model used rates developed previously by planners in the state of Pennsylvania for a similar project, which were later compared to actual trip counts and were found to overestimate bicycle trips by about 10 to 15 percent. These rates are provided in Table 1 of the paper; however, they are based on relatively old data from the 1980s. Of further interest are the models that provide correlations for variables thought to affect bicycle and pedestrian trips (i.e. Dade County Demand Models, North Central Texas Council of Governments' (NCTCG) Bicycle Needs Index, and NCTCG's Pedestrian Needs Index). Though these correlations are based on somewhat newer survey data (1990s) they are still outdated.

- University of North Carolina, Highway Safety Research Center. (1994). **A Compendium of Available Bicycle and Pedestrian Trip Generation Data in the United States.** http://drusilla.hsrc.unc.edu/cms/downloads/BikePedTripGenerationData1994.pdf

This report summarizes the findings of bicycle and pedestrian counts, surveys, and studies conducted in various cities to estimate the effects of bicycle and pedestrian facilities. The document includes many charts and tables displaying various bicycle and pedestrian counts conducted in cities throughout the United States. Overall, this document is a rich source of data (albeit quite old) and methodologies for bicycle and pedestrian trip data collection. As this research was focused on trip generation counts and estimates for bicycle and pedestrian facilities (e.g. bike lanes, sidewalks, recreational paths, etc.), it is not directly applicable to trip generation estimates for developments, but it provides an interesting assessment of what environmental factors influence biking and walking trips.

Of particular interest is a methodology for assessing pedestrian level of service (A through F) based on square feet per pedestrian, average speed, and flow rate taken from the Transportation Research Board's *Highway Capacity Manual.* However, other researchers (Seneviratne and Morrall, 1985) have argued that this is not an appropriate method of analyzing pedestrian level of service as it does not take into account enough environmental captures to account for an area's "walkability." Also of interest is Table 7-1 in this document, which presents rates of bicycle and walking for major trip purposes in large urban areas (>1 million) with rail transit, large urban areas without rail transit, and small urban areas (<1 million).

One interesting finding demonstrated in this table is that levels of biking and walking are usually similar between small urban areas and large urban areas without rail transit. Ultimately, this study found that data for bicycle trips were more readily available than data for pedestrian trips, potentially due to the relative ease of collecting bicycle data as opposed to collecting pedestrian data. Unfortunately no studies were found that assigned bicycle and pedestrian trip generation rates to a wide range of land uses. Thus, the authors recommend using local modal split data to convert ITE *Trip Generation* estimates into multi-modal trip generation rates

- Vernez Moudon, A., Kavage, S.E., Mabry, J.E., & Sohn, D.W. (2005). **A Transportation-Efficient Land Use Mapping Index.** *Transportation Research Record, 1902,* 134-144.

This paper explores a Transportation-Efficient Land Use Mapping Index (TELUMI) that was developed by the Washington State Department of Transportation (WSDOT) in order to better-evaluate the effects of land use patterns on Level of Service (LOS). The idea of Land Use Level of Service (LULOS) is introduced as a more comprehensive, less mode-specific alternative to traditional LOS. In a LULOS the capacity and characteristics of the entire transportation network for a given area would be examined relative to the total number network users, regardless of mode-choice. The result would be a multi-modal travel behavior model as opposed to models looking at LOS for single modes.

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WSDOT's TELUMI is an instrument which incorporates the concept of LULOS. TELUMI takes into account multi-modal networks, in addition to context-sensitive trip generation. Land use variables that relate to travel behavior are established, and then Cartographic Modeling (CM) techniques are used to explore the relationship between these variables and different levels of transportation-efficient land use. Then, different levels of transportation efficiency are identified, which correspond to standard LOS levels. The result is a tool which can receive a variety of different types and quantities of input and in turn produce a visual and quantitative output that is a better indicator of an area's true LOS for all network users. This tool also incorporates context-sensitive trip generation rates derived from ITE rates, but the methodology for doing so is not provided.

- Walters, G., Ewing, R., & Schroeer, W. (2000). **Adjusting Computer Modeling Tools to Capture Effects of Smart Growth: Or "Poking at the Project Like a Lab Rat."** *Transportation Research Record,* 1722, 17-26.

This paper describes the application of travel forecasting methods to determine the air quality impacts of a mixed-use, infill development centrally located in Atlanta that required construction of a bridge in order to make it a viable project. Many design and travel demand management variables known to affect travel demand (i.e. the "Ds") were taken into account in the analysis of this project, in order to determine whether such a project would have less environmental impact than a similar project in a less central, undeveloped area.

The literature on the Ds was used to develop adjustment factors, and analysis of the site was facilitated by the "INDEX" GIS-based scenario-planning tool. Ultimately it was determined that regional location and site design can be used to foster multi-modalism, which in turn can lead to reduced emissions and environmental impacts. Specifically, travel reductions for the mixed use, infill site were found to be 14 to 52 percent compared to development at greenfield locations. Such findings indicate a need for tools that analysts can use in order to determine reductions in trip generation from site location and design.

California Smart-Growth Trip Generation Rates Study

Final Report

Appendix C

Institute of Transportation Studies

University of California, Davis

Davis, CA 95616

Summary & Comparison of existing tools for estimating Trip Generation Rates for Smart Growth Land Uses

by Susan Handy, Richard Lee, and Rachel Maiss for the Caltrans/UCD "Smart Growth Trip-Generation Method" study
March 17, 2010

Introduction

This document summarizes various tools, as discovered by the research team, that aid traffic engineers (as well as project planners and developers) in estimating trip generation rates. In its search for tools, the team focused particularly on uncovering those that provide trip generation estimates for projects located within urban environments where transit and non-motorized transportation is more common. The ability of a tool to respond to location, density, mixed use, and design and other "D" factors (described in the Definitions document) that facilitate non-motorized travel was also a key consideration. In general, the search emphasized tools that are more context-sensitive than the traditional Institute of Transportation Engineers' (ITE) *Trip Generation* methodology, which, by virtue of its emphasis on surveys of land uses in suburban settings, tends to overestimate rates for developments incorporating one or more smart growth principles.

The majority of the tools summarized here are models designed to adjust the trip generation rates provided by ITE (or a similar set of rates compiled by the San Diego Association of Governments, SANDAG) in order to better reflect the effects of different land use mixes, density, design, location, and transportation attributes on trip generation. In addition to these types of tools, a few alternative tools will be described which do not rely as heavily (or at all) on the ITE/SANDAG rates. All of these tools provide transportation professionals with potential improvement over the traditional method of estimating trip generation rates for smart-growth projects. However, none of these tools are without flaws. This summary will serve as an guide to both what exists currently within the realm of trip generation rates tools, and what further improvements need to be made in order to more accurately estimate trip generation rates for smart growth type developments.

Tool Type 1: Adjustments to ITE/SANDAG Rates

ITE/SANDAG Rate Adjustments

	Pros	Cons
ITE *Trip Generation Handbook*	✓ Court tested ✓ Easy to use ✓ Provides peak-hour rates ✓ Accepted for use in traffic impact analyses (TIAs)	✗ Reductions based on a small sample size ✗ No consideration of D's ✗ No multi-modal output ✗ Tends to over-estimate
EPA MXD/SANDAG Mixed Use Model	✓ Easy to use ✓ Calculations are transparent ✓ Estimates have been validated ✓ Sensitive to D's ✓ Provides multi-modal output	✗ Only applicable to sites between 5 and 2000 acres ✗ Somewhat data intensive
Peter Eakland's Model	✓ Easy to use ✓ Calculations are transparent ✓ Provides distinct city center rates for some land use types	✗ No distinction between passby trips and non-motorized trips

Summary & Comparison of existing tools for estimating Trip Generation Rates for Smart Growth Land Uses

URBEMIS	✓ Easy to use ✓ Sensitive to D's ✓ Court tested ✓ Calculations are unable to be manipulated	× No peak-hour estimates × Calculations are not immediately transparent (“Black box” type interface)
NCHRP 8-51 Tool (Texas DOT)	✓ Calculations are transparent ✓ Provides multi-modal output ✓ Sensitive to Diversity/Mixed-use	× Very data intensive × Based on 6 surveyed sites

ITE Trip Generation

The ITE *Handbook* provides practitioners with guidance on the proper use of the data provided in *Trip Generation*, in addition to supplemental material regarding the trip generation estimation process. Chapter Seven of the *Handbook* provides a methodology for estimating trip generation rates at mixed-use sites, using a worksheet provided in the document. However, the analyst is instructed to “exercise caution” when using this methodology to estimate reductions, as the data represent a very small sample size, and all sites are located in a single state. Further, this methodology is only applicable to mixed use developments (MXDs) and does not account for other factors known to affect trip rates, such as density, transit availability, street design, etc. In fact, the *Trip Generation Handbook* specifically cautions against using ITE trip rates data in downtowns or locations served by transit[1]. Also, as trip generation rates calculated using this worksheet are expressed as reductions from the vehicle trip generation rates provided in *Trip Generation*, no modal split information is provided using this methodology. Though *Trip Generation* is widely used and accepted since it was developed by ITE, and is the most cited authority on trip generation estimates in the United States, it exhibits the aforementioned drawbacks.

EPA MXD Model/SANDAG Mixed Use Model

These two tools can be analyzed together as they adjust trip estimates using the same elasticities for a set of land use and transportation variables known to affect trip generation. These models provide reductions to vehicle trip estimates in ITE's *Trip Generation* or San Diego's *Traffic Generators* (a tool similar to *Trip Generation*, but specific to the San Diego area). These reductions to vehicle trips are categorized as internally captured trips within MXDs, walking/biking external trips, or transit external trips (“external” refers to trips outside of a MXD site or neighborhood). The EPA tool is in spreadsheet format, with some basic data input required by the analyst. These tools take into account the “D-factors” in land use known to affect travel, and their vehicle trip estimates have been validated at more than 40 sites mostly in California. The most significant drawback to these models is that they have been formally validated only for sites ranging from 5 to 2000 acres in size. A method of accounting for smaller and single-use developments within mixed use developments or other “smart growth” neighborhoods is currently has been developed and tested by SANDAG and its consultants

1 ITE *Trip Generation Handbook, Second Edition*. June 2004. Page 15: “If the site is located in a downtown setting, served by significant public transportation, or is the site of an extensive transportation demand management program, the site is **not consistent with the ITE data** and the analyst should collect local data and establish a local rate.”

Summary & Comparison of existing tools for estimating Trip Generation Rates for Smart Growth Land Uses

Peter Eakland's Model

Peter Eakland, an independent transportation planner, developed a tool that provides an input module for analysts to estimate trip generation using the numbers in the City of San Diego's *Traffic Generators* (a somewhat more detailed version of SANDAG's *Traffic Generators*). This tool puts rates and equations into a spreadsheet format, which makes the trip generation estimation process more user-friendly and transparent. Other attractive features of this tool include its ability to estimate city center vehicle trip rates, and to take into account vehicle trips generated by existing developments. One drawback is that it provides no distinction between non-motorized and passby trips (these are all grouped under "passby"). Further, it does not account for the "D-factors" known to affect trip generation rates as it is based purely on the information provided in *Traffic Generators*.

URBEMIS

This tool, which stands for "urban emissions", was originally created by the California Air Resources Board (ARB) in order to facilitate the assessment of criteria pollutant emissions from light-duty vehicle travel related to land use projects in California. During the late 1990s, it was upgraded and a "mobile source mitigation component" added under the direction of a consortium of air quality management districts in California, who continue to update and disseminate URBEMIS via the Internet. Among other things, it is capable of estimating trip generation for MXDs using one or two of the aforementioned "D-factors". It is a very user-friendly tool and has withstood several legal challenges for use in air quality impacts analyses of land use projects in California. However, because it was developed as an air quality analysis tool, it does not provide peak-hour trip generation rates which are of significant importance in traffic impact studies. Further, the interface of this software provides the user with no insight into the calculations being performed so its transparency is somewhat limited; however, the analyst can find descriptions of most of the module's calculations in the user's guide. This "drawback" could potentially be viewed as an advantage as the calculations cannot be inappropriately manipulated by the user.

NCHRP 8-51 Method and Spreadsheet Tool

The National Cooperative Highway Research Program (NCHRP) is in the midst of finalizing a project (*Enhancing Internal Trip Capture Estimation for Mixed-Use Developments*) aimed at outlining a methodology for analysts to collect appropriate data in order to estimate internal capture rates for MXDs, and apply these rates as reductions to trip generation rates. This tool is in spreadsheet format, which enhances its user transparency. In addition to internal capture rates, it provides mode split estimates, which is ideal for a tool of this kind. However, since this tool is meant to assist analysts in collecting their own trip generation rates data, it is extremely data intensive and thus unlikely to be used as a primary trip generation estimation tool.

Summary & Comparison of existing tools for estimating Trip Generation Rates for Smart Growth Land Uses

Tool Type 2: Organized Empirical Database Tools

Organized Empirical Database Tools

	Pros	Cons
UK's TRICS	✓ Easy to use ✓ Based on a large amount of up-to-date survey data ✓ Provides multi-modal output ✓ Context-sensitive (urban v. suburban)	× Only applicable to developments in the UK
New Zealand Trips and Parking Database	✓ Based on up-to-date survey data ✓ Provides multi-modal output ✓ Context-sensitive (D's)	× Only applicable to developments in New Zealand

UK's TRICS

The Trip Rate Information Computer System (TRICS) is a trip generation rates tool that has been used in the United Kingdom since 1989. It is a comprehensive and dynamic database consisting of trip generation estimates based on actual vehicle counts as well as multi-modal survey data for a variety of different land use types (located in England, Scotland, Wales, and Ireland). Trip generation estimates for proposed land use projects are multi-modal (based on multi-modal data), and sensitive to urban versus suburban locational factors. Users have access to all of the survey data from existing land uses to estimate trip generation, as well as detailed information regarding the survey sites. The database is updated with new survey data every three months. The TRICS system is an exemplary tool for calculating multi-modal trip generation rates, though it is clearly not applicable to developments in the United States as it is based solely on UK data.

New Zealand Trips and Parking Database

This tool is similar to TRICS in the sense that it is a comprehensive database of trip generation rates data. It provides users with information on trip generation rates based on land use groups and activity subgroups. The Trips and Parking Database, like TRICS, provides multi-modal estimates, and seems to be context-sensitive to an even higher degree than the TRICS database, utilizing more of the "D-factors" that affect trip generation. However, this database is only directly applicable to developments in New Zealand.

Tool Type 3: Person-trip Based Tools

Person-trip Based Tools

	Pros	Cons
San Francisco method	✓ Easy to use ✓ Based (at least somewhat) on up-to-date survey data	× Based on supplemental data solely from San Francisco × Data are not specific to Ds × Calculations are not transparent

San Francisco Method

The *Transportation Impact Analysis Guidelines for Environmental Review,* as published by the Planning Department of the City and County of San Francisco in 2002, provides a trip generation methodology used in analyzing developments in the City and County of San Francisco. This tool is in the form of a look-up table with trip rates (per square feet) for various land use types. Unique to this tool is its ability to estimate person-trips in place of vehicle-trips, and to estimate modal split based on local travel survey data. The tool itself is based on a combination of ITE's *Trip Generation*, data from the San Francisco Citywide Travel Behavior Survey, and various environmental impact report traffic analyses. Although most of San Francisco consists of dense urban typically mixed-use development, the data used to create this tool are not specifically analyzed in terms of the “D-factors”. There’s also uncertainty regarding the accuracy of using travel survey data to estimate trip generation rates for individual sites. Further, as this tool is based on San Francisco survey data, its applicability outside the City and County of San Francisco is questionable.

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Final Report

Appendix D

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University of California, Davis

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Evaluation of the Operation and Accuracy of Five Available Smart Growth Trip Generation Methodologies

Richard Lee
Josh Miller
Rachel Maiss
Mary Campbell
Kevan Shafizadeh
Deb Niemeier
and Susan Handy
Institute of Transportation Studies
University of California, Davis

with Terry Parker
California Department of Transportation

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Richard Lee, Josh Miller, Rachel Maiss, Mary Campbell, Kevan Shafizadeh, Deb Niemeier, and Susan Handy
with Terry Parker, for the California Department of Transportation
Institute of Transportation Studies
University of California, Davis
Revised 9/18/12

Executive Summary

No standard methodology exists in the U.S. for estimating trip generation that takes into account the smart growth characteristics of a land use development project. As a first step toward developing such a methodology, this report assesses the available alternatives to the traditional ITE *Trip Generation* methodology. We identified eight available methods. For five of these methods, we completed a two-part assessment. The first part was to evaluate the methods against a variety of operational criteria developed through discussions with a panel of transportation practitioners. The second part was to test the accuracy of the methods by comparing the predictions of the various methods against available traffic counts and other data at 22 California sites that have at least some characteristics of smart growth

Existing Methodologies
We searched for existing tools that provide trip generation estimates for projects located within urban environments where transit and non-motorized transportation is more common. Most of the identified tools adjust the ITE trip generation rates to better reflect the effects of location, density, mixed land uses, and other design characteristics on trip generation. In addition, we identified two other types: tools that provide rates based on trip generation data collected at sites with smart growth characteristics, and one tool that uses person-trip data from a travel survey. Of these eight, we determined that five were candidate methodologies:

1. The current ITE *Handbook* Chapter 7 method for Multi-use development (referred to as **ITE Multi-use method**).
2. The EPA/SANDAG MXD Multi-use analysis method developed for the US EPA and subsequently adapted for use in the SANDAG region (**EPA MXD**).
3. The NCHRP 8-51 method, based on a recently completed research project. It is an enhancement of the current ITE Handbook Chapter 7 method (**NCHRP 8-51**).
4. A prototype method that adjusts ITE trip generation rates using travel survey with factors derived from data compiled by the Metropolitan Transportation Commission in the San Francisco Bay Area (**MTC Survey**).
5. URBEMIS 2007, the most recent version of a tool developed for analysis of emissions from land development projects, including mobile source emissions (**URBEMIS**).

Evaluation of Candidate Methods on Operational Criteria

We evaluated each of the five candidate methods with respect to key operational criteria identified and rated on their importance by a panel of transportation practitioners with experience in traffic impact analysis. The operational criteria are grouped into the following categories: 1) Ease of use; 2) Sensitivity to key smart growth elements; 3) Input requirements; 4) Output features; and 5) Usability of a methodology or tool in helping to define smart growth projects based on their performance.

No clear "winner" emerges among currently available methods based on the operational criteria; the methods all both meet and fall short of desired goals. However, criteria highly rated by the panel could be focal points in considering the merits of both existing methods and a final preferred methodology (Table ES-1).

Table ES-1: Top-Rated Criteria

Criterion	Criteria Type	Average Rating from 1-6 (6=Highest Rating)
1. Sensitivity of output to inputs	Input Data Mechanics	6.0
2. Results replicable by other analysts	Output	5.8
3. Results should not fluctuate excessively.	Additional Criteria	5.6
4. Method measures the performance of different kinds of land use projects	Additional Criteria	5.6
5. AM / PM / daily / Other time frames reported	Output	5.4
6. Auto vs. "other" trip generation rates	Output	5.3
7. LU context variables	Sensitivity	5.1
8. "Internal capture" shown	Output	5.0
9. Project-level Variables	Sensitivity	5.0
10. Transport Variables	Sensitivity	4.9
11. Project description by land use(s) and size	Output	4.9

Evaluation of the Accuracy of Candidate Methods

Panel members unanimously ranked accuracy as the highest priority criterion for trip generation estimation methodologies. To assess the relative accuracy of each of the five candidate methods, we compared available cordon counts at ten multi-use sites and twelve infill sites in California against estimates produced by the methodologies. These methods were also compared to the industry standard ITE trip generation rates for single land uses. The summary tables in the report show the error for each method, calculated as the percentage deviation between the actual traffic count and the estimate. Two summary statistics were also computed for each method: the average error, calculated as the sum of the errors for all sites divided by the number of sites; and the average absolute error, calculated as the sum of the absolute values of the errors for all sites divided by the number of sites.

Table ES-2 (below) indicates *for each site* the method that most accurately matches the observed traffic counts for the two sets of land use sites. For sites where the raw ITE rate is the best match, the candidate method that mostly closely matches the observed count is also shown. For the multi-use sites, all of which are large-scale projects not located in a central business district, the EPA MXD method produces the most accurate estimate in the greatest number of sites. It is not surprising that the EPA MXD method is most accurate for the multi-use sites, given that these sites were chosen based on their similarity to the sites used to calibrate the method. For the single-use urban infill sites, a clearly best method does not emerge.

Conclusions

This report provides an assessment of five candidate smart growth trip generation methodologies with respect to their performance regarding operational criteria and their accuracy. The results show that all of the candidate methodologies performed better than the ITE rates, but they do not point to a clear "winner" – one methodology that is clearly superior to the others. Nevertheless, this assessment generated many insights that could guide the selection or development of a recommended methodology.

These initial results also point to the critical need for further collection of trip generation data at smart growth sites. Based on only 22 sites, the evaluation presented here is not adequate to fully assess the performance of available methods. In addition, the validation sites do not reflect the full spectrum of smart growth development projects but instead cluster around two extremes – large multi-use suburban sites, and individual urban infill projects. Data from more sites of more types are needed to better understand the performance of the available methods.

Table ES-2. Most Accurate Method for Each Evaluation Site (Showing Method with Lowest Error Rate)							
Multi-Use Site and Location	**Daily**	**% Error**	**AM Peak Hour**	**% Error**	**PM Peak Hour**	**% Error**	**Notes on Site**
Gateway Oaks, Sacramento	ITE Multi-Use	0%	na		na		Large site, little use mix
Jamboree Center, Irvine	EPA MXD	-3%	MTC survey	9%	MTC survey	5%	Large site, little use mix
	ITE Rate	*1%*					
Park Place, Irvine	EPA MXD	15%	EPA MXD	23%	EPA MXD	20%	Mulit-use, low-density
	MTC Survey	15%					
The Villages, Irvine	URBEMIS	-7%	MTC survey	0%	URBEMIS	8%	Higher density, lowest WalkScore (40)
Rio Vista Station Village, San Diego	EPA MXD	4%	MTC survey	28%	URBEMIS	2%	Multi-use suburban, LRT
La Mesa Village Plaza, San Diego	EPA MXD	-5%	EPA MXD	10%	EPA MXD	-12%	Multi-use suburban, LRT
	ITE Rate	*-3%*	NCHRP 8-51	-10%	URBEMIS	-12%	
Uptown Center, San Diego	EPA MXD	1%	URBEMIS	3%	EPA MXD	10%	Multi-use urban; no rail
The Village @Morena Linda Vista, San Diego	EPA MXD	11%	MTC survey	22%	MTC survey	19%	Multi-use suburban, LRT
Hazard Center, San Diego	URBEMIS	2%	NCHRP 8-51	11%	MTC survey	7%	Office+retail, LRT no res'l
Heritage Center @ Otay Ranch, Chula Vista	EPA MXD	-20%	URBEMIS	10%	ITE Multi-	-3%	Suburban, no LRT
	ITE Rate	*-13%*					
Infill Study Site and Location							
Retail, Oakland	na		EPA MXD	-92%	EPA MXD	-18%	Retail only, Oakland
			ITE Rate	*-92%*	*ITE Rate*	*-7%*	
Office, San Francisco	na		EPA MXD	-17%	NCHRP 8-51	-2%	Office Only, CBD
Office, Los Angeles	na		URBEMIS	-23%	URBEMIS	-3%	Office Only, CBD
Residential, San Diego	na		MTC Survey	101%	EPA MXD	31%	High–rise res'l, CBD
Residential, San Diego	na		MTC Survey	-6%	MTC Survey	4%	Res'l + coffee shop, CBD
Office, Los Angeles	na		URBEMIS	79%	URBEMIS	-3%	Office Only, CBD
Office, Los Angeles	na		URBEMIS	-25%	MTC Survey	-3%	Office Only, CBD
Residential, San Diego	na		NCHRP 8-51	-7%	URBEMIS	2%	Mid–rise res'l Only, CBD
Residential, Pasadena	na		NCHRP 8-51	-25%	NCHRP 8-51	1%	High–rise res'l Only,
			URBEMIS	-25%			
			ITE Rate	*-12%*			
Residential, San Francisco	na		NCHRP 8-51	-14%	NCHRP 8-51	-15%	High–rise res'l Only, CBD
Restaurant, San Francisco	na		EPA MXD	12%	NCHRP 8-51	3%	Quality restaurant only
					MTC Survey	3%	
Restaurant, San Francisco	na		NCHRP 8-51	24%	EPA MXD	-20%	Quality restaurant only
					ITE Rate	*-10%*	

Evaluation of the Operation and Accuracy of Five Available Smart Growth Trip Generation Methodologies

1. Introduction

Many communities are encouraging development that follows “smart growth” principles – higher densities, mixed land uses, infill locations – as a strategy for reducing vehicle travel. A substantial body of evidence suggests that vehicle use is generally lower in such developments (Ewing and Cervero 2010). However, forecasting the effects of any single smart growth development on traffic is difficult. In compliance with the California Environmental Quality Act (CEQA), developers in California must estimate the transportation impacts of their proposed developments in the form of a Traffic Impact Analysis (TIA). Often developers are required to mitigate these traffic impacts by paying impact fees or providing facility improvements. The basis for such mitigation is the project's TIA. Accuracy in TIAs is thus important to ensure that mitigations are adequate but not excessive.

Estimating the number and type of trips that a development project will produce is the first step of a TIA, a step known as “trip generation.” The guidance used most often for estimating trip generation is the Institute of Transportation Engineers' (ITE) *Trip Generation.* This manual provides average vehicle trip generation rates (daily and peak-hours) for a variety of land use categories. However, the data used in *Trip Generation* are mostly collected at isolated developments that lack public transit and good bicycle and pedestrian infrastructure. Thus, the manual specifies that while these rates are appropriate for conventional suburban developments, they should not be used in downtowns or other areas served by transit, where the ITE rates tend to overestimate the vehicle trips.

Despite an awareness of this limitation, no standard methodology exists in the U.S. for estimating trip generation that takes into account the smart growth characteristics of a development project. Because of the lack of a standard methodology, analysts sometimes improvise. But improvised methods often produce more controversial results than the standard technique using the ITE’s *Trip Generation* rates, if only because the latter is the standard. To avoid this controversy and its potential legal ramifications, many analysts revert to using the ITE rates, even when they recognize their limitations. Applying the ITE rates to smart growth projects is likely to produce over-estimates of vehicle trips and may lead to mitigation measures that over-emphasize vehicle needs while under-supplying appropriate transit, bicycle, and pedestrian facilities.

As a first step toward the development of a standard trip generation methodology for smart growth projects, this report assesses the available alternatives to the ITE rates. We identified eight available methods, as described in Section 2. For five of these methods, we completed a two-part assessment. The first part was to evaluate the methods against a variety of operational criteria developed through discussions with a panel of transportation practitioners (described in Section 3). The second part was to test the accuracy of the methods by comparing the predictions of the various methods against available traffic counts and other data at 22 California sites that have at least some characteristics of smart growth (described in Section 4). As summarized in Section 5, the results of this assessment do not point to a clear “winner” but provide important insights for the effort to develop a smart growth trip generation methodology.

2. Available Methods

2.1 Background

Many studies have illuminated the drawbacks of the ITE *Trip Generation* methodology, especially when this method is used to estimate trip generation rates for development projects with smart growth characteristics. For instance, one study concluded that "...traffic impact studies for mixed use developments are little more than exercise in speculation" (Ewing et al. 2001). Similar findings have been made at transit-oriented developments (TODs) as well as infill developments. One infill development study using traffic counts and intercept surveys found that, with the exception of a few sites, observed trips were an average of 26 to 40 percent lower during peak periods than those indicated by the ITE method (Kimley Horn & Associates 2009).

In another study, traffic counts at TODs found that residential TODs averaged 44 percent fewer vehicle trips than those estimated by ITE (Arrington and Cervero 2008). Based on a multivariate regression analysis, this study also found that residential density within one-half mile of the transit station is the variable most correlated with trip generation rates. Thus, the risks of overestimating trip generation rates for TODs are significant. Typically, higher trip generation estimates lead to increased parking provisions, which in turn can lead to lower development density. In effect, inaccurate ITE data can create a feedback cycle in which developers decide to decrease density and increase parking provision at a TOD in order to get the development approved, which in turn leads to less transit use than originally anticipated, and which ultimately reaffirms initial concerns regarding the traffic impacts of the development. This study concluded that more accurate predictions of TOD-generated traffic are essential for TODs to reach their full potential.

Overestimation of trips using ITE rates is not limited to TODs. In one analysis, case studies at actual developments showed that ITE peak-hour trip generation rates often overestimated traffic impacts, regardless of development type (Muldoon and Bloomberg 2008). Researchers in that study attributed the overestimation to improper ITE land-use code selection, inadequate assessment of pass-by trip reductions, failure to consider seasonal variations in traffic counts, and lack of multi-modal evaluation. Such studies indicate that planners need a more flexible, context-sensitive, and accurate trip generation tool to produce traffic impact analyses.

2.2 Existing Methodologies

We searched for existing tools that provide trip generation estimates for projects located within urban environments where transit and non-motorized transportation is more common. A key consideration was the tool's ability to respond to location, density, mixed land uses, and other design characteristics that have been found to facilitate non-motorized travel. In general, the search emphasized tools that are more context-sensitive than the traditional ITE *Trip Generation* methodology.

A majority of the identified tools adjust the ITE trip generation rates (or an alternative set of rates compiled by the San Diego Association of Governments (SANDAG)) to better reflect the effects of location, density, mixed land uses, and other design characteristics on trip generation. In addition to this type of tool, we identified two other types: tools that provide rates based on trip generation data collected at sites with smart growth characteristics, and one tool that uses person-trip data from a travel survey. All of these tools are potentially better than the traditional ITE *Trip Generation* method, though none is without flaws. This section describes each identified tool.

2.1.1 Adjustments to ITE/SANDAG Rates

- **ITE Trip Generation**

The ITE *Trip Generation Handbook* (*Handbook*) guides practitioners on the proper use of the data provided in *Trip Generation,* and includes supplemental material regarding the trip generation estimation process. Chapter Seven of the *Handbook* provides a methodology for estimating trip generation rates at mixed-use sites, using a worksheet in the document. However, the analyst is instructed to "exercise caution" when using this methodology to estimate reductions, as the data on which the method is based come from a very small sample of sites, and all sites are located in a single state. According to the *Handbook*, this methodology is only applicable to multi-use developments and does not account for other factors known to affect trip rates, such as density, transit availability, street design, etc. In fact, the *Handbook* specifically cautions against using ITE trip rates data in downtowns or locations served by transit.[1] Also, because trip generation rates calculated using this worksheet are expressed as reductions from the ITE vehicle trip generation rates, there is no modal split information. Though *Trip Generation* is widely used and is the most cited authority on trip generation estimates in the United States, it has serious drawbacks, as listed above.

- **EPA MXD Model/SANDAG Mixed-Use Model**

These two tools are assessed together because they adjust trip estimates using the same elasticities for any given set of land use and transportation variables. The elasticities were derived from travel survey data collected at 239 multi-use developments[2] in six metropolitan regions around the United States. These models reduce the vehicle trip estimates in ITE's *Trip Generation* or San Diego's *Traffic Generators* (a tool similar to *Trip Generation*, but specific to the San Diego area). These reductions to vehicle trips are categorized as internally-captured trips within multi-use developments, walking/biking external trips, or transit external trips ("external" refers to trips outside of a multi-use site or neighborhood). The EPA tool is in spreadsheet format, with some basic data input requirements. These tools take into account the "D-factors" in land use known to affect travel (i.e. density, diversity (land use mix), design (usually measured as street connectivity), distance to transit, "destination accessibility," and others). The EPA MXD tool has been validated at 16 sites in the U.S. for which vehicle trip counts were collected; six of these sites are in California. The SANDAG tool has been validated at six sites in the San Diego region for which vehicle trips counts were collected, as well as 20 areas in that region for which an adequate number of records were available from the SANDAG 2006 Regional Household Travel Behavior Survey.

- **Eakland's Model**

Peter Eakland, an independent transportation planner, developed a tool that provides an input module for analysts to estimate trip generation using the numbers in the City of San Diego's *Traffic Generators* (a somewhat more detailed version of SANDAG's *Traffic Generators*). This tool puts rates and equations into a spreadsheet format, which makes the trip generation estimation process more user-friendly and transparent. Other attractive features of this tool include its ability to estimate city center

[1] ITE *Trip Generation Handbook, Second Edition*. June 2004. Page 15: "If the site is located in a downtown setting, served by significant public transportation, or is the site of an extensive transportation demand management program, the site is **not consistent with the ITE data** and the analyst should collect local data and establish a local rate." [*Emphasis added.*]

[2] Although the method is labeled "MXD" for "mixed-use development," we reserve the use of this term for areas where land uses are mixed at a finer grain, as is typically found in a downtown or town center. The 239 sites used in the cited study are more appropriately labeled "multi-use" in that they tend to have larger blocks of single land uses separated by arterial streets and are thus less walkable.

vehicle trip rates, and its ability to take into account vehicle trips generated by existing developments. One drawback is that it provides no distinction between non-motorized and pass-by trips (these are all grouped under "pass-by"). Further, it does not account for land use characteristics such as density and mix of uses as it is based purely on the information provided in *Traffic Generators*.

- **URBEMIS**

This tool, which stands for "urban emissions," was originally created by the California Air Resources Board to facilitate the assessment of criteria pollutant emissions from light-duty vehicle travel related to land use projects in California. During the late 1990s, it was upgraded and a "mobile source mitigation component" added under the direction of a consortium of air quality management districts in California, which continued to update and disseminate URBEMIS via the Internet until recently. Among other things, URBEMIS is capable of estimating trip generation for smart growth developments based on various land use, locational, and transportation characteristics. It is a user-friendly tool and has withstood several legal challenges for use in air quality impacts analyses of land use projects in California. However, because it was developed as an air quality analysis tool, it does not provide peak-hour trip generation rates which are of significant importance in traffic impact analyses. Further, the interface of this software provides the user with little insight into the calculations being performed, so its transparency is somewhat limited. However, the analyst can find descriptions of most of the module's calculations in the user guide. This limitation could potentially be viewed as an advantage as the calculations cannot be inappropriately manipulated by the user.

- **NCHRP 8-51 Method and Spreadsheet Tool**

The National Cooperative Highway Research Program (NCHRP) is in the midst of finalizing a project (*Enhancing Internal Trip Capture Estimation for Mixed-Use Developments*) aimed at outlining a methodology for analysts to collect appropriate data in order to estimate internal capture rates for multi-use developments,[3] and to apply these rates as reductions to trip generation rates. This tool is in spreadsheet format, which enhances its user-transparency. In addition to internal capture rates, it provides mode split estimates, which is ideal for the analysis of smart growth projects. However, since this tool is meant to assist analysts in collecting their own trip generation rates data, it is extremely data-intensive and thus unlikely to be used as a primary trip generation estimation tool.

2.1.2 Organized Empirical Database Tools

- **UK's TRICS**

The Trip Rate Information Computer System (TRICS) is a trip generation rates tool that has been used in the United Kingdom (UK) since 1989. It is a comprehensive and dynamic database consisting of trip generation estimates based on actual vehicle counts and multi-modal survey data for a variety of different land use types at numerous locations (in England, Scotland, Wales, and Ireland). The system is based on multi-modal data and provides trip generation estimates for multiple travel modes for proposed development projects. Further, the estimates are sensitive to urban versus suburban locational factors. Users have access to all of the available survey data from existing development to estimate trip generation, as well as detailed information regarding the survey sites and collection dates. The database is updated with new survey data regularly, and data older than ten years is removed. The

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[3] Although the title of the project used the term "mixed-use development," we label the sites "multi-use development" for reasons noted in Footnote 2.

TRICS system is an exemplary tool for calculating multi-modal trip generation rates of proposed development projects of various types, locations and designs. However, it is based solely on UK data.

- **New Zealand Trips and Parking Database**

This tool is similar to TRICS in that it is a comprehensive database of trip generation rates data. It provides users with information on trip generation rates based on land use groups and activity subgroups. The Trips and Parking Database, like TRICS, provides multi-modal estimates, and seems to be context-sensitive to an even higher degree than the TRICS database, utilizing even more of the factors found to affect trip generation. However, this database is only directly applicable to developments in New Zealand.

2.1.3 Person-Trip Based Tools

- **San Francisco Method**

The *Transportation Impact Analysis Guidelines for Environmental Review,* published by the Planning Department of the City and County of San Francisco in 2002, provides a trip generation methodology used in analyzing developments proposed in the City and County of San Francisco. This tool is in the form of a look-up table with trip rates (per square feet) for various land use types. Unique to this tool is its ability to estimate person trips in place of vehicle trips, and to estimate mode split based on local travel survey data. The tool itself is based on a combination of ITE's *Trip Generation*, data from the San Francisco Citywide Travel Behavior Survey, and traffic analyses from various environmental impact reports. However, the accuracy of using travel survey data to estimate trip generation rates for individual sites is uncertain. Further, as this tool is based on San Francisco survey data, its applicability outside San Francisco is questionable.

2.3 Candidate Methods

In the remainder of this report, we assess five available “candidate” methods as to: 1) which, if any, of the methods best meet operational requirements (Section 3), and 2) which may be the most accurate for what types/locations of land use projects (Section 4). We omitted three methods from this assessment: the UK’s TRICs and the New Zealand Trips and Parking Database, because the data are not applicable to California; and Ekland’s model, because it is based solely on San Diego data. In place of the San Francisco method, we tested a survey-based approach based on analysis of travel survey data for the San Francisco Bay Area provided by the Metropolitan Transportation Commission. The five available candidate methods examined were:

6. The current ITE *Handbook* Chapter 7 method for Multi-use development (referred to as **ITE Multi-use method**).
7. The EPA/SANDAG MXD Multi-use analysis method developed for the US EPA and subsequently adapted for use in the SANDAG region (**EPA MXD**).
8. The NCHRP 8-51 method, based on a recently-completed research project; it is an enhancement of the current ITE Handbook Chapter 7 method (**NCHRP 8-51**).
9. A prototype method that adjusts ITE trip generation rates using travel survey with factors derived from data compiled by the Metropolitan Transportation Commission in the San Francisco Bay Area (**MTC Survey**).

10. URBEMIS 2007, the most recent version of a tool developed for analysis of emissions from land development projects, including mobile source emissions (**URBEMIS**).

Summaries of key features of each of these methods are listed in Table 1. Appendix A provides detailed information about each of these methodologies (including detailed references). It also lists the key data sources and assumptions used to test the accuracy of each method in estimating traffic generation at 22 multi-use and infill sites in California for which traffic cordon count data is available (the results of which are described in Section 4 of this report).

Table 1: Brief Overview of Five "Candidate" Methodologies

ITE Handbook Multi-use Methodology* • Available and in use since 2001. • Calculates internalization of trips due to multiple land uses only. • Daily and PM peak hour – no AM. • Based on only three cases studies – all in Florida. • Does not predict the mode of internalized trips (e.g., driving, walk/bike, shuttle or transit). • Does not account for other on-site or context variables (such as density, location, design, etc.). * Source: *ITE Trip Generation Handbook, 2nd Edition. June 2004*
EPA MXD Method • Developed for US EPA based on analysis of travel survey data at multi-use sites in six metro areas in the U.S.* The San Diego Association of Governments (SANDAG) adopted it for use in June 2010. • Key Inputs (in addition to land uses): o Area (in acres); number of intersections within project. o Employment within one mile of the multi-use development. o Employment that can be reached from project within a 30-minute transit trip. • Outputs: reductions for internal capture, and external transit and pedestrian/bicycle trips. * See: "EPA Mixed Use Trip Gen Research 05 09.pdf" on the Project website; and *Trip Generation for Smart Growth: Planning Tools for the San Diego Region*, SANDAG, June 2010. http://www.sandag.org/tripgeneration
NCHRP 8-51 Method • Enhanced version of ITE Handbook Multi-use methodology. • Based on data collected at six sites. • Provides PM peak hour rates, plus AM peak hour (Current ITE Method lacks AM estimate). • Method operationalized in a spreadsheet. • Tested at two sites in Texas & one in Georgia. • Requires data on mode split and vehicle occupancy, ideally in peak hours and by inbound/outbound. • For this report, mode split data from the 2000 MTC Travel Survey was used for all the Multi-use sites (the only daily, two-way modal data available). For the Infill sites, intercept survey data was used (that was collected for the California Infill Trip Generation Rates study*). *Kimley-Horn & Associates, et.al., *Trip-Generation Rates for Urban Infill Land Uses in California, Final Report*, June, 2009.
MTC Survey-based method • A travel survey-based method was suggested by a panel member. Based on detailed analysis of the Metropolitan Transportation Commission's (MTC) 2000 Travel Survey of the SF Bay Area* • Adjusts ITE vehicle trip rates based on urban environment (density) and proximity to rail/ferry transit. * Station Area Residents Survey (StaRS), 2006: http://www.mtc.ca.gov/planning/smart_growth/stars/
URBEMIS* ("Urban Emissions") • Air quality analysis tool for estimating daily vehicle trips and emissions of land use projects in CA. • Uses ITE trip rates (7^{th} Edition of Trip Generation; not yet updated to the 8^{th}). • "Mobile Source Mitigation Component" includes some context variables (density, mixed-use, transit, street connectivity, bicycle and pedestrian facilities, transportation-demand management). • Does not predict peak hour trips; some consultants estimate for peak hours based on ITE Trip Generation data (this method was also used for this report). * URBEMIS 2007 (version 9.2.4) http://urbemis.com/

3. Evaluation of Candidate Methods on Operational Criteria using Survey Rankings

This section evaluates each of the five candidate methods using a number of key operational criteria identified by a panel of transportation practitioners with experience in traffic impact analysis (Practitioners Panel). During several conference calls, the panelists discussed the qualities – in addition to accuracy – that they most require in a smart growth trip generation rates estimation methodology. From these discussions, we compiled a list of operational criteria and reviewed them with the panelists. Based on our experience in applying each method (as described in Section 4 and Appendix A), we rated the methods regarding each criterion.

We then invited panelists to rate the criteria regarding their relative importance via an on-line survey. Eight members of the Practitioners Panel responded to the on-line survey (see full results in Appendix C). Respondents were asked to rate each criterion from one to six with one being "least important" and six being "most important." The average of all responses for each criterion is shown in the right column of Tables 3 through 7. The criteria are arranged according to the average ratings from highest-rated to lowest-rated in each category.

The Practitioners Panel's operational criteria are grouped into the following categories: 1) Ease of use; 2) Sensitivity to key smart growth elements; 3) Input requirements; 4) Output features; and 5) Usability of a methodology or tool in helping to define smart growth projects based on their performance. Definitions of subjective criteria (terms such as "Low," "Moderate," "High," and "User-friendliness") that are used in the evaluations of operational criteria are shown in Table 2.

Table 2: Subjective Criteria Definitions

Criteria	Low	Moderate	High
User-friendliness	Basic understanding of the method requires more than a day	Basic understanding of the method requires more than an hour but under a day	Basic understanding of the method requires under an hour
Transparency	Source and magnitude of effects of adjustments to trip rate not readily apparent	Source and magnitude of effects of adjustments to trip rate somewhat apparent	Source and magnitude of effects of adjustments to trip rate readily apparent
Data needs	Little or no data needed beyond that required to use ITE trip rates	Some data needed beyond that required to use ITE trip rates	Substantial data needed beyond that required to use ITE trip rates
Difficulty of obtaining required data	All relevant data readily obtainable from public sources	Most relevant data readily obtainable from public sources	Unpublished data needed, or extensive data collection by analyst required
Effort to use available data	Little interpretation or judgments about data required	Up to three interpretations or judgments about data required	More than three interpretations or judgments about data required
Sensitivity of output to inputs	Many inputs reduce the effect of any single factor	Several inputs have a moderate effect on outputs	One or two inputs greatly affect output

3.1 Evaluation Results

The first set of criteria identified by the Practitioners Panel addresses the relative difficulty or ease of using each of the methods. Table 3 compares each of the candidate methods against specific components of ease of use. (Note that for the last criterion - "time to analyze a project composed of three land uses" - it was assumed that the user starts with a site plan with land uses, quantities, and site area.)

Table 3: Ease of Use Criteria*

Criterion	ITE Multi-use	EPA MXD	NCHRP 8-51	MTC Survey	URBEMIS	Average Survey Rating
1. **User-friendliness**	Moderate	Moderate	Moderate	High	Moderate	4.8
2. **Difficulty of obtaining required data**	Low	High	High	Low	Low	4.8
3. **Transparency**	High	Moderate	High	High	Low	4.1
4. **Data needs**	Low	Moderate	High	Low	High	4.1
5. **Time to analyze a Project** (with three land uses)	<30 minutes	30-60 min. *(if required data is readily available)*	30 min. *(note: including land use interchange distance data & mode split survey adds one day)*	<30 minutes	2 hours	3.4
6. **Use voluntary**	Yes	Yes	Yes	Yes	Yes	2.3

Elaboration of Criteria in Table 3 (based on Practitioners Panel input):

1. Is the tool user-friendly? (i.e., Can architects, planners, and junior engineers with little/no experience use it?)
2. Is needed input data readily available?
3. Is the methodology transparent?
4. How much data needs to be input to use the methodology?
5. How much time is required to run the methodology (using available data)?
6. Will use of the methodology be voluntary?

Based on all the criteria in Table 3, the ITE Multi-use and MTC Survey methods emerge as the easiest to use, while URBEMIS, the EPA MXD, and NCHRP 8-51 methods are more challenging, each for slightly different reasons. URBEMIS' data needs are high in terms of the number of items an analyst must enter; however sources for this data are easily found. The number of data items required for the EPA MXD method is fewer, but one required item – the number of jobs accessible within 30 minutes by transit – is difficult to calculate manually without a regional model, and analysts in some regions may not have easy access to such regional modeling data. The NCHRP 8-51 method has fewer inputs than either URBEMIS or MXD, but detailed data on mode of access to a project site is not readily available, and collecting such data at sites comparable to the project site would be labor intensive.

Responding practitioners rated user-friendliness and ease in obtaining data as their most important criteria regarding ease of use, reaffirming the favorable status of the ITE Multi-use and MTC Survey methods in this category. Respondents did not consider the voluntary use of the methodology to be an important criterion, and the time required to analyze a project did not rate highly.

The second set of criteria identified by the Practitioners Panel addresses how sensitive each method or tool is to important factors that affect project trip generation, especially factors that define projects as smart growth. Table 4 compares the methods against specific sensitivities that practitioners identified as important. As in Table 3, the criteria are shown as rated by the respondents to the on-line survey, with the highest-rated criteria listed first.

Table 4: Method Sensitivities Criteria*

Criterion	ITE Multi-use	EPA MXD	NCHRP 8-51	MTC Survey	URBEMIS	Average Survey Rating
1. LU context variables	No	Yes	No, except via mode split	Yes	Yes	5.1
2. Project-level Variables	Yes (land use mix only)	Yes	Yes (land use mix only)	No	Yes	5.0
3. Transport Variables	No	Yes	Via mode split	Yes	Yes	4.9
4. Transit headways/ Change in service	No	Indirectly, via employment within 30 minutes	No, except via mode split	No	Yes	4.3
5. Urban design variables	No	Intersection density	No, except via mode split	No	Yes – several	4.0
6. Parking supply/pricing	No	No	No	No	Yes	3.9
7. Pedestrian/ Bicycle Connectivity	No	Indirectly, via number of intersections and employment within 1 mile	Yes	No	Yes	3.7
8. Use of 7Ds	1 D	6 Ds	2 Ds	2 Ds	5 Ds	3.4
9. Starts with person trips, then allocates to modes	No	No	No; estimates person trips	No	No	2.4
10. Gas Prices	No	No	No	No	No	2.0

***Elaboration of Criteria in Table 4 (based on Practitioner Panel input):**

- Is the method or tool sensitive to:
  1. Land use/context-sensitive variables? Density and mix of surrounding uses.
  2. Project level variables? (Especially spatial distribution) – e.g. density and mixed use.
  3. Transportation variables? e.g., proximity to transit, nearby pedestrian & bike facilities.
  4. Transit headways/Changes in Transit service?
  5. Urban design variables? Pedestrian friendliness, traffic calming.
  6. Parking supply and pricing?
  7. Pedestrian connectivity? e.g. density of walkways.
  8. Does it use the 7Ds methodology? Can it prioritize Ds by estimated sensitivity?
  9. Does it start with person trips, then allocate to modes? (Considered ideal).
  10. Gas prices?

Examination of all Table 4 criteria indicates that URBEMIS and the EPA MXD method are the most sensitive to key smart growth variables regarding this category. The NCHRP 8-51 method is sensitive to some of these variables, while the ITE Multi-use and MTC Survey method are the least sensitive.

In reviewing the highest-rated sensitivity criteria (over 4.0), URBEMIS and EPA MXD are again the preferred methods, along with NCHRP 8-51 with mode split applied. Respondents favored sensitivity to the surrounding land-use variables as the most important criterion, followed closely by project-specific and multi-modal sensitivity. It is interesting to see that based on this rating, sensitivity regarding the surrounding environment scored slightly higher than sensitivity to the actual project and mode data. It is also interesting to note that “sensitivity to gas prices” and “starting with person trips” were rated as not important in this context.

The third set of criteria identified by the Practitioners Panel concerns the mechanics of preparing the input data. Table 5 compares each of the candidate methods against specific criteria regarding input data requirements and characteristics. The average rating from panelists via the on-line survey is shown in the column on the right.

Table 5: Input Data Mechanics Criteria*

Criterion	ITE Multi-use	EPA MXD	NCHRP 8-51	MTC Survey	URBEMIS	Average Survey Rating
1. Sensitivity of output to inputs	High, since few inputs	Moderate, several inputs	High, since few inputs	High, since few inputs	Moderate, several inputs	6.0
2. Uses local information	No	Yes	Via mode split	Yes	Yes	4.6
3. Difficulty of obtaining required data	Low	High	High	Low	Low	4.6
4. Amount of data needed about the proposed project	Land use quantities (LUQ)	LUQ plus HH size & Vehicle Ownership	LUQ plus mode split data	LUQ	LUQ plus mitigation data	4.6
5. Can it work without regional or local travel models?	Yes	Yes; more effort if no model	Yes	Yes	Yes	4.5
6. 2-tiered data inputs for data-poor/-rich areas	No	No	No	No	No	4.5
7. Borrowed data OK	No	No	No	To be determined	No	4.3
8. Amount of data needed about the project's context &/or area nearby	None	Two data items	None	One item	Several data items	4.3
9. Relates Smart Growth indicators to inputs	No	Yes Intersection density	No, except via mode split data	No	Yes	4.1
10. Effort to use available data	Low	Moderate	Moderate	Low	High	3.6

Elaboration of Criteria in Table 5 (based on Practitioner Panel input):

1. How sensitive is the final result to the data input?
2. Does method require some local information?
3. How easy is it to access/find input data? (Ideally method uses data that is available.)
4. How much input data is project-level?
5. Can method work without regional or local travel models?
6. Is it two-tiered for more and less sophisticated data environments? (Is there a process for areas without good data or models? e.g., possibly "lookup" tables in lieu of regional or modeling data.)
7. If input data is lacking, does method allow for borrowing from other, similar sources?
8. How much input data is larger contextual data?
9. Does a tool relate smart growth indicators to inputs?
10. How difficult is it to operate the methodology using available data?

The evaluation summarized in Table 5 indicates that the EPA MXD method and the NCHRP 8-51 method are the most demanding with respect to input data availability. URBEMIS is the most demanding in terms of the amount data that needs to be input. The ITE Multi-use and MTC survey-based methods are the least demanding in terms of data availability and input.

Overall, survey respondents gave input mechanics criteria high importance ratings, with sensitivity of outputs to inputs receiving the highest possible score (6) from every respondent. Respondents' ratings show that input mechanics are a priority and that the availability of local data is of high importance in evaluating a preferred methodology. URBEMIS scores well in the prioritized criteria for its use of local data and the ease of acquiring these data; it also has the most demanding data requirements, but respondents gave relatively low importance to this criterion.

The fourth set of criteria identified by the Practitioners Panel concerns the outputs that are calculated and reported by each of the methods. Table 6 compares the methods against specific criteria related to outputs and shows the on-line Panel survey results.

Table 6: Method Output Criteria*

Criterion	ITE Multi-use	EPA MXD	NCHRP 8-51	MTC Survey	URBEMIS	Average Survey Rating
1. **Results replicable by other analysts?**	Yes	Yes	Yes	Yes	Yes	5.8
2. **AM / PM / daily / other time frames reported?**	PM / Daily	AM/PM/ Daily	AM/PM	AM/PM/ Daily	Daily only	5.4
3. **Auto vs. "other" trip generation rates**	Auto only	Auto, Transit, Non-motor	Auto, Transit, Non-motor	Auto, Transit, Non-motor	Auto only	5.3
4. **"Internal capture" shown?**	Yes	Yes	Yes	No	Yes	5.0
5. **Project description by land use(s) and size?**	Yes	Yes	Yes	Yes	Yes	4.9
6. **Input assumption?**	Yes	Yes	Yes	Yes	Yes	4.6
7. **Analyst can adjust model?**	No	Yes	Yes	No	Yes	4.5
8. **Include and distinguish between future traffic volumes and a project's trip generation rate?**	No non-project trips	No non-project trips	No non-project trips	No non-project trips	No non-project trips	4.0
9. **Effect of bike and pedestrian facilities on travel?**	No	Yes	No	No	Yes	3.9
10. **Graphical representation of raw vs. final trip gen. data?**	No	No	No	No	No	3.8
11. **Link reduced trips to a reduction in vehicle-miles traveled (VMT)?**	No	Possible with more data	No	No	Yes	3.4

12. **Effect of transit service on travel?**	No	Yes	Yes	Yes	Yes	3.3

The data in Table 6 indicate that most methods produce and report a significant number of the outputs desired by practitioners. None of the methods produce all desired outputs. In particular, all the methods lack graphical display of outputs.

URBEMIS stands out as the one method that does not produce peak hour results because it was designed to estimate air quality effects, not for traffic impact studies. While this shortcoming has been addressed by practitioners and in our assessment (through the application of peak hour factors from ITE Trip Generation data, as described in Appendix A), it adds another layer of complexity to this method.

Survey respondents gave high ratings to many of the output criteria, as they did for the input criteria. Most importantly, results need to be replicable, a criterion satisfied by all methodologies. Respondents also wanted multi-modal reports on multiple time frames. This criterion favors the EPA MXD, NCHRP 8-51 and MTC Survey methods, although the latter does not show internal capture, another highly-rated criterion. Consistent with ratings in Tables 4 and 5, respondents favor local, project-specific information both as an input and an output. Respondents were only somewhat concerned with linking reduced trips to a reduction in vehicle-miles traveled or knowing how transit availability affected travel.

The Practitioners Panel also identified several other criteria and topics, shown in Table 7 in the order of importance as rated by respondents in the survey.

Table 7: Additional Criteria

Criterion	ITE Multi-use	EPA MXD	NCHRP 8-51	MTC Survey	URBEMIS	Average Survey Rating
1. **Results should not fluctuate excessively**	See Section 4 (Evaluation of Accuracy)					5.6
2. **Can the method measure the performance of different kinds of land use projects?**	Theoretically, each method could potentially be used to do this, if it is sufficiently accurate based on adequate traffic count data for a sufficiently broad range of sites					5.6
3. **Can the method be used to define a range of reductions in ITE rates?**	Theoretically, each method could potentially be used to do this, if it is sufficiently accurate based on adequate traffic count data for a sufficiently broad range of sites					4.3
4. **Does the method identify a context for a development that qualifies it as smart growth?**	Theoretically, each method could potentially be used to do this, if it is sufficiently accurate based on adequate traffic count data for a sufficiently broad range of sites					3.6

5. **Can the method define different categories of smart growth based on size, urban area, etc?**	Theoretically, each method could potentially be used to do this, if it is sufficiently accurate based on adequate traffic count data for a sufficiently broad range of sites	3.6
6. **Complex equations should be converted to simpler graphs and/or tables**	Although this analysis has not been done for any of the methods, converting equations to graphs or tables would appear to be a straightforward procedure, especially for methods implemented as spreadsheets.	3.6
7. **Can the method group certain types of smart growth within parameters to comprehend complex development mixes?**	Theoretically, each method could potentially be used to do this, if it is sufficiently accurate based on adequate traffic count data for a sufficiently broad range of sites	3.4

Many of these additional criteria relate to whether the method can be used to measure and define different types and levels of smart growth based on performance as estimated by the method. As noted, any of the methodologies should be able to meet these objectives, depending on the data and the range of sites. Section 4 of this report presents evidence regarding the fluctuation of results, a highly-rated criterion in this category. The emphasis practitioners placed on repeatability and flexibility in general over specific relationships to "smart growth" is particularly interesting.

In addition to the above listed criteria, the Practitioners Panel highlighted the ability to encourage and facilitate the use of a preferred method as important for any chosen methodology.

3.3 Conclusions

No clear "winner" emerges among currently available methodologies based on the Practitioners Panel operational criteria. However, survey respondents prioritized a number of criteria that could be focal points in considering the merits of both existing methodologies and a final preferred methodology. However, survey results should be considered in light of the small initial respondent pool. It could be useful to survey a broader sample of practitioners as well as additional constituencies such as policymakers and regulators.

With respect to the operational criteria described above, the methods all both meet and fall short of desired goals:

- The current ITE Multi-use method has modest data needs, but does not consider any land use and transportation contextual factors beyond the project boundaries. It also does not predict AM peak hour trip generation, which is necessary for most traffic impact analyses.

- The EPA MXD method is fairly sensitive to smart growth characteristics and has moderate data needs. However, the availability of required input data can be challenging, particularly regarding employment within a 30-minute transit trip. This data need can be met by a fairly simple exercise of a regional travel demand model, if one is available, accessible, and models transit. However, such models are not universally accessible in California at this time.

- The NCHRP 8-51 method is less data intensive than either URBEMIS or the EPA MXD methods. However, one data requirement – directional mode split information for comparable projects in the AM and PM peak periods – is not readily available and has proved challenging to collect via surveys. The method does not make explicit consideration of land use and transportation contextual factors beyond the project boundaries, although if accurate mode split data can be obtained, such data would be reflective of the project's context.

- The MTC Survey method has very modest data needs, but it does not consider on-site characteristics (e.g. the mix of land uses, density, connectivity, etc.). The method's basis (the MTC 2000 Bay Area Travel Survey) may not be applicable to other regions in California, although it would potentially be possible to analyze travel survey data from other regions to produce more localized adjustment factors.

- URBEMIS is very comprehensive with respect to its sensitivity to smart growth factors. Required input data is readily available for URBEMIS, but it takes the most time to operate due to the need to analyze census and other available input data. Also, URBEMIS does not currently provide peak hour estimations, which must therefore be obtained from other sources for use in traffic impact analyses (if available).

The results of the initial Practitioners Panel survey on operational criteria provide guidance for the selection of an existing methodology or development of new methodologies. The top-rated criteria across all categories, as shown in Table 8, suggest that respondents favored specific output criteria (five of the 11 highest-rated) followed by method sensitivity (three of the 11) as most important. Interestingly, no "ease of use" criterion scored higher than a 4.8, suggesting that the practitioners who responded to our on-line survey favor results from an input-sensitive methodology over one that is easier to use. They also prefer a method that works for various land types, not only smart growth development, and has results that are not analyst-dependent. Respondents consistently noted the importance of a method using local context-sensitive data from both the project as well as the surrounding environment.

Table 8: Top-Rated Criteria

Criterion	Criteria Type	Average Rating
12. Sensitivity of output to inputs	Input Data Mechanics	6.0
13. Results replicable by other analysts	Output	5.8
14. Results should not fluctuate excessively.	Additional Criteria	5.6
15. Method measures the performance of different kinds of land use projects	Additional Criteria	5.6
16. AM / PM / daily / Other time frames reported	Output	5.4
17. Auto vs. "other" trip generation rates	Output	5.3
18. LU context variables	Sensitivity	5.1
19. "Internal capture" shown?	Output	5.0
20. Project-level Variables	Sensitivity	5.0
21. Transport Variables	Sensitivity	4.9
22. Project description by land use(s) and size?	Output	4.9

Because the survey results are based on a limited number of responses (8) and a select group of respondents (Practitioners Panel members), they may not be generalizable. Other practitioners, city council members, agency regulators, or interest-based policy groups could have different perspectives on desired sensitivities, outputs, and other "operational criteria" for trip generation methodologies. It is important to consider what different user groups would prefer in a new trip generation methodology, both to ensure its wide acceptance and broad usefulness.

4. Evaluation of the Accuracy of Candidate Methodologies

The Practitioners Panel identified the ability to accurately predict trip generation for projects as the most important criterion against which each method should be measured. To assess the relative accuracy of each of the five candidate methods, we compared available cordon counts at ten multi-use sites and twelve infill sites in California against estimates from the five candidate methodologies. These methods were also compared to the industry standard ITE trip generation rates for single land uses (referred to as **ITE rates**).[4]

Traffic count data used to evaluate the accuracy of the candidate methodologies come from two sources: 1) daily and peak-hour traffic counts at 10 sites in California originally collected for validation of the EPA/SANDAG MXD method[5] (referred to hereafter as the "**Multi-Use sites**"); and 2) peak hours cordon count and intercept survey data for 12 infill sites that was gathered for Caltrans' *Trip-Generation Rates for Urban Infill Land Uses in California* study[6] (referred to hereafter as the "**Infill sites**"). Most of the Multi-Use sites are medium to large-scale developments (5 to 200+ acres) located outside urban cores. By contrast, the Infill sites are single uses located in urban cores close to high-quality transit. Appendix B provides information about each of the sites.

Three summary tables present the results of the evaluation of the five candidate methodologies. Table 9 summarizes results for daily counts, for the multi-use sites only (daily counts were not available for the infill sites). Table 10 summarizes results for AM peak hour counts, for both multi-use and infill sites. Table 11 summarizes results for PM peak hour counts, for both multi-use and infill sites. Figures associated with each table help to illuminate the comparisons.

The summary tables show the error for each method, calculated as the percentage deviation between the actual traffic count and the estimate.[7] Two summary statistics were also computed for each method: the average error, calculated as the sum of the errors for all sites divided by the number of sites; and the

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[4] Institute of Transportation Engineers, *Trip Generation*, 8th Edition.

[5] Although 12 of the validation sites are in California, we chose to exclude two sites, South Davis and Moraga because these areas are too large for appropriate use of trip-generation rates. See the draft documentation (EPA Mixed Use Trip Gen Research 05 09.pdf); and *Trip Generation for Smart Growth: Planning Tools for the San Diego Region*, SANDAG, June 2010 (*http://www.sandag.org/tripgeneration).*

[6] Kimley-Horn & Associates, et.al, *Trip-Generation Rates for Urban Infill Land Uses in California*, *Final Report* for Caltrans, June, 2009. *http://www.dot.ca.gov/research/researchreports/reports/2009/final_summary_report-calif._infill_trip-generation_rates_study_july_2009.pdf*

[7] Several entries in the tables are missing, for various reasons. The NCHRP method does not produce daily estimates. The EPA/SANDAG method estimates are missing for five infill sites because of the unavailability of a key input, employment accessible within 30 minutes by transit. The ITE Multi-use method does not produce AM peak hour estimates and is not applicable to infill sites. AM and PM peak hour counts were not available for Gateway Oaks, a multi-use site in Sacramento.

average absolute error, calculated as the sum of the absolute values of the errors for all sites divided by the number of sites. A positive average error indicates that the method, on average, overestimates vehicle trips, while a negative average error indicates that the method underestimates vehicle trips. The absolute average error corrects for the fact that a method that overestimates in half the cases and underestimates by the same amount in the other half would have a misleading average error of 0%.

It is important to note that the results presented here depend on the assumptions used in applying the methods, as described in Table 1 and in Appendix A, and on the assumptions used in preparing the input data. Repeating the analysis with different assumptions could produce different results and lead to different conclusions about the performance of each methodology with respect to accuracy.

4.1 Daily Counts

Estimated daily counts and error rates are shown in Table 9. Note that the NCHRP 8-51 method does not produce estimates of daily counts. As shown in the table, the ITE Multi-use method and the EPA MXD method tied for the lowest average error (6%) for the Multi-use sites, while the EPA MXD method had the lowest average absolute error (11%). This result is perhaps not surprising, given that the multi-use sites were chosen because they are similar in scale and composition to the sites used to calibrate the EPA MXD method. Average and absolute errors for the other methods are generally comparable to or greater than those for ITE rates (average error of 9% and average absolute error of 19%). The fact that ITE rates are as accurate as most of the methods may suggest that the multi-use sites in the EPA study are not all full-fledged examples of smart growth regarding location, density, and site design. In particular, the Gateway Oaks site (in Sacramento) and the three Irvine sites are larger (and hence more spread out) than the others and do not appear particularly walkable (see site descriptions in Appendix B).

Figure 1a shows estimated counts plotted against observed counts for each method for each site. The points mostly cluster around the diagonal line representing estimated counts equal to observed counts. Estimates for the three largest sites for the SANDAG trip rates stand out as significantly higher than the observed counts. Error rates, calculated as the difference between estimated and observed counts divided by observed counts, for the SANDAG Rates method are substantially higher than for other methods, as seen in Figure 1b, particularly for the Park Place site in Irvine. As shown in Table 9, all of the methods are more accurate than using unadjusted SANDAG trip generation rates at these sites. On average, SANDAG rates overestimate vehicle trip generation at the 10 multi-use sites by 40%.

4.2 AM Peak Hour

Estimated counts and error rates for the AM peak hour are shown in Table 10, first for the multi-use sites, then for the infill sites. Note that the ITE Multi-use method does not produce estimates for the AM peak hour, and key input data were missing for the EPA MXD method for several of the sites. Again, the EPA MXD method produced the lowest average error and absolute average error for the multi-use sites, at 14% and 27%, respectively. All methods, however, had significantly lower errors than the ITE rate. Note that the errors were generally greater for the AM peak than for daily counts, as can be seen in Figures 2a and 2b.

For the infill sites, URBEMIS produced the lowest average error, at 8%, and the lowest average absolute error, at 51%. Again, all methods had significantly lower errors than the ITE rate. However, the errors for the infill sites were generally much higher than for the multi-use sites, as can be seen in Figures 3a and 3b. The error rates, shown in Figure 3b, are higher for the smaller infill sites, and mostly reflect over-estimates of AM counts.

4.3 PM Peak Hour

Estimated counts and error rates for the PM peak hour are shown in Table 11, first for the multi-use sites, then for the infill sites. Note that input data were missing for the EPA MXD method for several of the sites and that the ITE Multi-use method cannot (without modification) be applied to the infill sites. PM peak hour counts were also not available for one MXD site.

For the PM peak hour, the MTC Survey method produces the lowest average error, at 5%, but the EPA MXD method produces the lowest average absolute error, at 22%. As before, this result is not surprising, given that the multi-use sites were selected to resemble the multi-use sites used in calibrating the EPA MXD method. All methods but the ITE Multi-use method produce lower average errors than the ITE rates. As shown in Figures 4a and 4b, the methods tend to err in the same direction and to similar degrees for each site. For example, the errors are all quite high for Park Place and for Jamboree, both in Irvine.

For the infill sites, URBEMIS produced the lowest average error, at -4%, and the second lowest average absolute error, at 29%. Again, all methods had significantly lower errors than the ITE rate. The ITE rate error was especially high for one of the residential sites in San Francisco. In contrast to the AM peak hour errors, the PM peak hour errors were generally about the same for the infill sites and for the multi-use sites. However, as can be seen in 5a, 5b, and 5c, the variation in errors for any particular site was much greater than for the multi-use sites. As was the case for AM peak hour estimates, the error rates for the smaller infill sites tend to reflect over-estimates of PM counts. Errors for some of the larger sites are comparable to the errors for the smaller sites. The MTC survey method and the NCHRP 8-51 method produce errors over 100% for some sites.

Table 9. Daily Trip Estimates vs Counts

Mixed-Use Site and Location	Daily Count	Trip Generation Rates				Candidate Methods							
		ITE Rate Estimate	ITE Rate Error	SANDAG Rates Estimate	SANDAG Rates Error	ITE Multi-Use Estimate	ITE Multi-Use Error	EPA MXD Estimate	EPA MXD Error	MTC Survey Estimate	MTC Survey Error	URBEMIS Estimate	URBEMIS Error
Gateway Oaks, Sacramento	**23,280**	23,984	3%	33,593	44%	23,333	0%	21,274	-9%	20,960	-10%	19,897	-15%
Jamboree Center, Irvine	**36,569**	36,918	1%	54,133	48%	35,529	-3%	31,996	-13%	32,263	-12%	33,142	-9%
Park Place, Irvine	**19,064**	25,157	32%	41,356	117%	24,501	29%	22,008	15%	21,985	15%	23,334	22%
The Villages, Irvine	**7,128**	8,808	24%	8,435	18%	8,790	23%	7,886	11%	7,697	8%	6,623	-7%
Rio Vista Station Village, San Diego*	**5,307**	7,216	36%	6,689	26%	7,101	34%	5,538	4%	3,991	-25%	4,324	-19%
La Mesa Village Plaza, San Diego*	**4,280**	4,146	-3%	5,681	33%	4,057	-5%	4,539	6%	2,293	-46%	3,024	-29%
Uptown Center, San Diego*	**16,886**	11,376	-33%	20,214	20%	10,786	-36%	17,097	1%	9,942	-41%	8,487	-50%
The Village at Morena Linda Vista, San Diego*	**4,712**	5,438	15%	6,375	35%	5,367	14%	5,251	11%	3,007	-36%	3,909	-17%
Hazard Center, San Diego*	**11,644**	14,703	26%	15,051	29%	14,427	24%	13,214	13%	8,131	-30%	11,890	2%
Heritage Center at Otay Ranch, Chula Vista*	**7,935**	6,870	-13%	10,505	32%	6,383	-20%	9,730	23%	6,004	-24%	11,007	39%
Average error			**9%**		**40%**		**6%**		**6%**		**-20%**		**-8%**
Average absolute error			**19%**		**40%**		**19%**		**11%**		**25%**		**21%**

*San Diego and Chula Vista sites use SANDAG rates in their MXD estimates

Note: NCHRP method does not produce daily estimates.

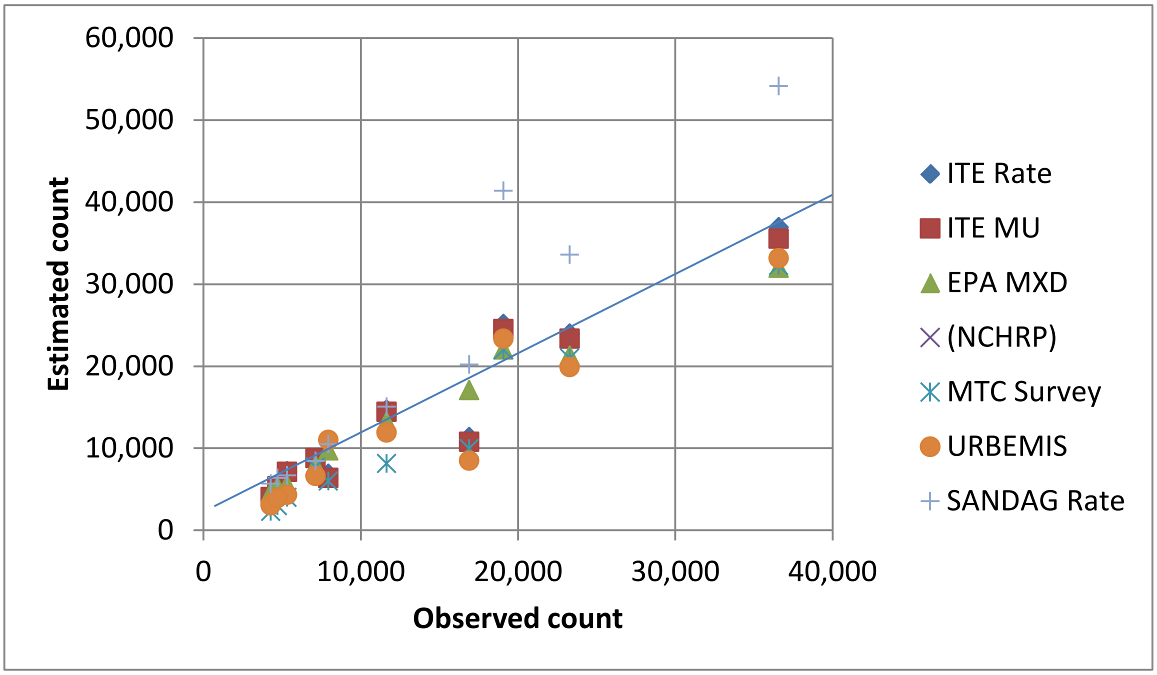

Figure 1a. Estimated versus Observed Count – **Daily for Multi-Use Sites**

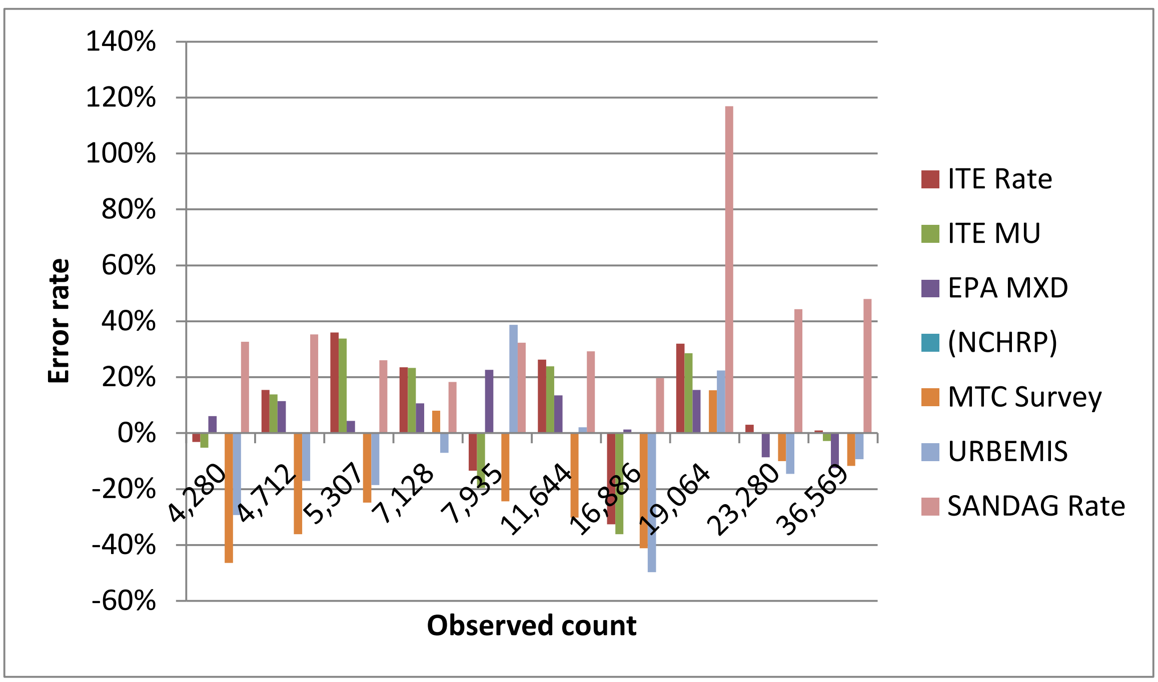

Figure 1b. Error Rate versus Observed Count – **Daily for Multi-Use Sites**

Table 10. AM Peak Hour Trip Estimates vs Counts

Mixed-Use Site and Location	AM Peak Hour Count	Trip Gen Rates		Candidate Methods									
		ITE Rate Estimate	ITE Rate Error	ITE Multi-Use Estimate	ITE Multi-Use Error	EPA MXD Estimate	EPA MXD Error	NCHRP 8-51 Estimate	NCHRP 8-51 Error	MTC Survey Estimate	MTC Survey Error	URBEMIS Estimate	URBEMIS Error
Gateway Oaks, Sacramento	missing	2,684	**na**	**A**	**na**	1,555	**na**	2,185	**na**	2,346	**na**	2,235	**na**
Jamboree Center, Irvine	3,125	3,893	25%	**A**	**na**	2,393	-23%	3,847	23%	3,402	9%	3,512	12%
Park Place, Irvine	1,295	3,068	137%	**A**	**na**	1,594	23%	2,454	89%	2,681	107%	2,841	119%
The Villages, Irvine	664	757	14%	**A**	**na**	565	-15%	652	-2%	662	0%	584	-12%
Rio Vista Station Village, San Diego	280	650	132%	**A**	**na**	431	54%	391	40%	359	28%	400	43%
La Mesa Village Plaza, San Diego	302	456	51%	**A**	**na**	331	9.8%	273	-9.6%	252	-16%	333	10.3%
Uptown Center, San Diego	638	882	38%	**A**	**na**	770	21%	776	22%	771	21%	658	3%
The Village at Morena Linda Vista, San Diego	315	693	120%	**A**	**na**	391	24%	419	33%	383	22%	511	62%
Hazard Center, San Diego	614	1,575	157%	**A**	**na**	938	53%	679	11%	871	42%	1,273	107%
Heritage Center at Otay Ranch, Chula Vista	667	485	-27%	**A**	**na**	553	-17%	882	32%	424	-36%	737	10%
Average error			**72%**				**14%**		**26%**		**19%**		**40%**
Average absolute error			**78%**				**27%**		**29%**		**31%**		**42%**

A = Method does not produce AM peak hour estimates and is not applicable to infill sites

B = Missing input data (Employment within 30 min. by transit)

Table 10 AM Peak Hour Trip Estimates vs Counts - continued

Infill Site and Location	AM Peak Hour Count	Trip Gen Rates		Candidate Methods									
		ITE Rate Estimate	ITE Rate Error	ITE Multi-Use Estimate	ITE Multi-Use Error	EPA MXD Estimate	EPA MXD Error	NCHRP 8-51 Estimate	NCHRP 8-51 Error	MTC Survey Estimate	MTC Survey Error	URBEMIS Estimate	URBEMIS Error
Retail, Oakland	133	11	-92%	A	na	10	-92%	6	-95%	6	-95%	4	-97%
Office, San Francisco	145	186	28%	A	na	120	-17%	114	-21%	109	-25%	92	-37%
Office, Los Angeles	110	210	92%	A	na	B	na	200	82%	160	46%	84	-23%
Residential, San Diego	21	72	241%	A	na	45	113%	56	165%	42	101%	45	113%
Residential, San Diego	132	212	61%	A	na	75	-43%	113	-14%	125	-6%	145	10%
Office, Los Angeles	28	140	393%	A	na	B	na	128	350%	82	190%	51	79%
Office, Los Angeles	63	131	110%	A	na	B	na	123	97%	100	59%	47	-25%
Residential, San Diego	33	37	11%	A	na	B	na	31	-7%	28	-15%	29	-13%
Residential, Pasadena	39	34	-12%	A	na	B	na	29	-25%	26	-33%	29	-25%
Residential, San Francisco	21	126	499%	A	na	42	100%	18	-14%	74	252%	40	90%
Restaurant, San Francisco	14	17	24%	A	na	15	12%	6	-56%	10	-27%	8	-42%
Restaurant, San Francisco	11	33	214%	A	na	30	186%	13	24%	19	85%	17	62%
Average error			**131%**				**37%**		**40%**		**44%**		**8%**
Average absolute error			**148%**				**80%**		**79%**		**78%**		**51%**

A = Method does not produce AM peak hour estimates and is not applicable to infill sites

B = Missing input data (Employment within 30 min. by transit)

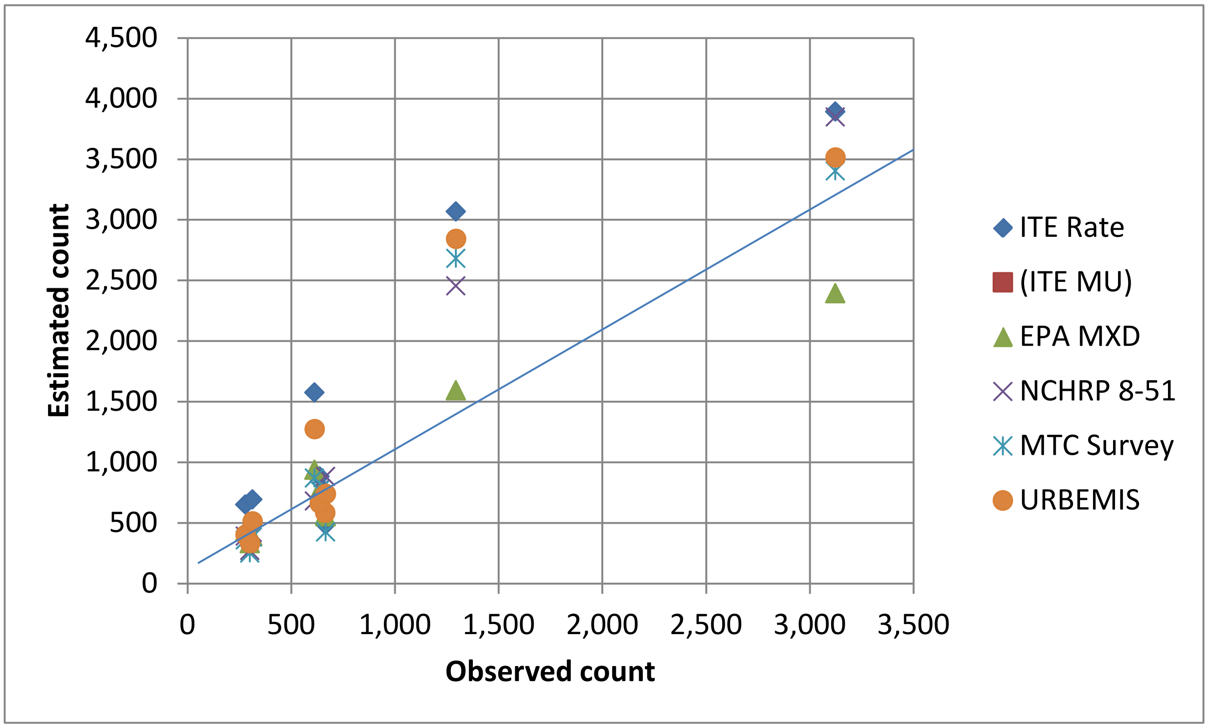

Figure 2a. Estimated versus Observed Count – **AM Peak Hour for Multi-Use Sites**

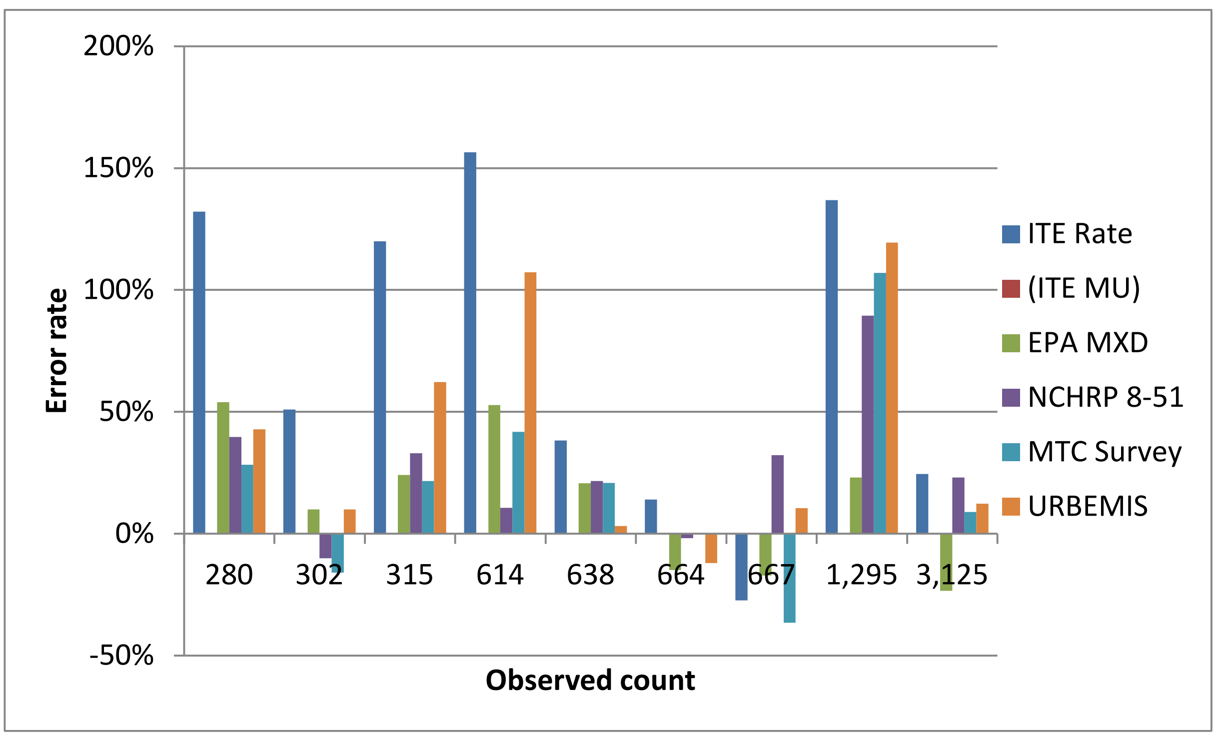

Figure 2b. Error Rate versus Observed Count – **AM Peak Hour for Multi-Use Sites**

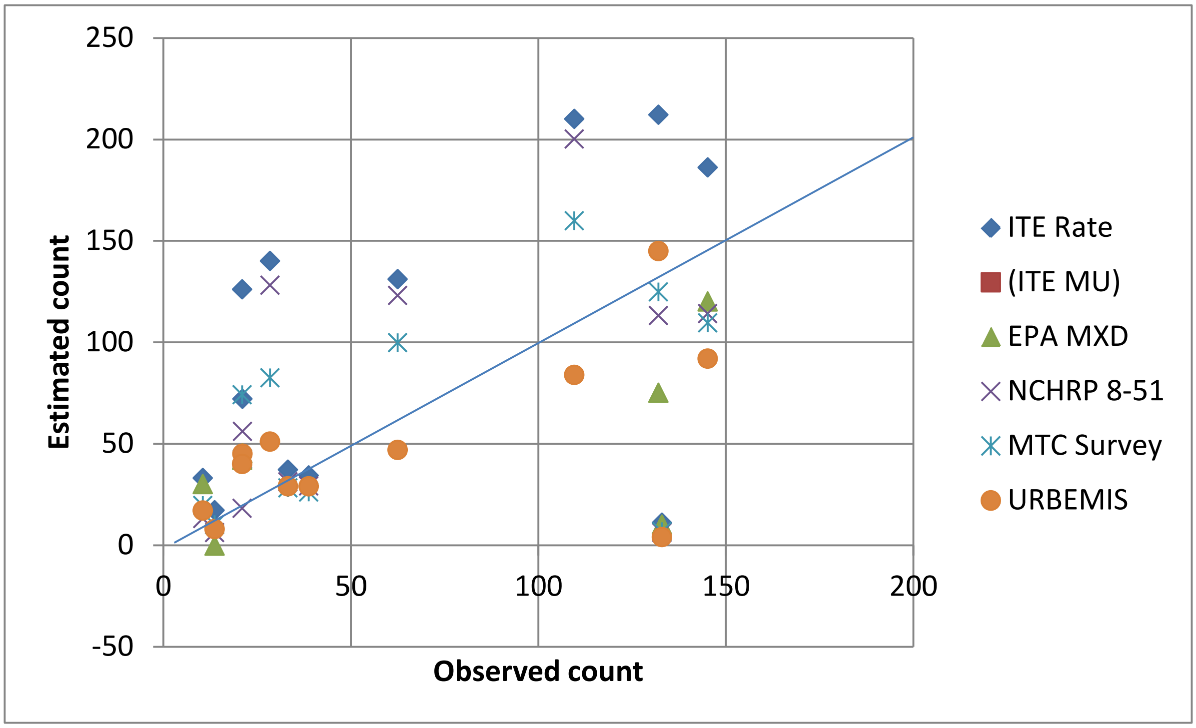

Figure 3a. Estimated versus Observed Count – **AM Peak Hour for Infill Sites**

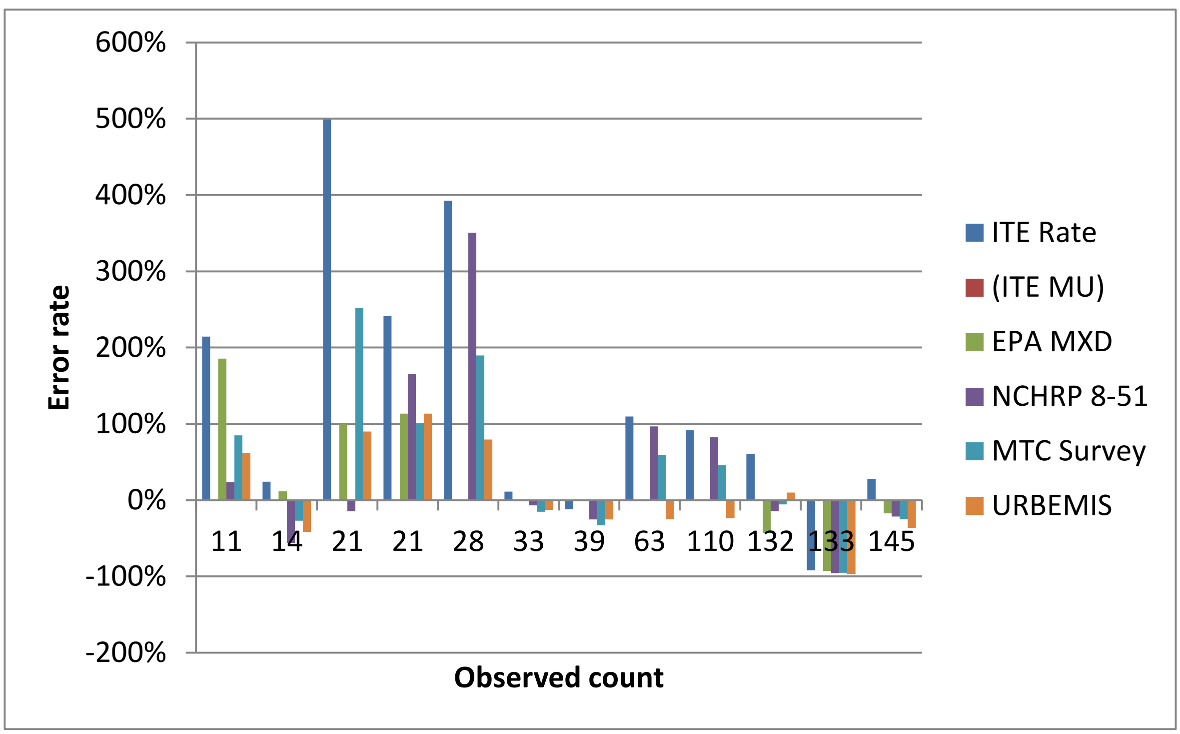

Figure 3b. Error Rate versus Observed Count – **AM Peak Hour for Infill Sites**

Table 11. PM Peak Hour Trip Estimates vs Counts

		Trip Gen Rates		Candidate Methods									
Mixed-Use Site and Location	**PM Peak Hour Count**	**ITE Rate Estimate**	**ITE Rate Error**	**ITE Multi-Use Estimate**	**ITE Multi-Use Error**	**EPA MXD Estimate**	**EPA MXD Error**	**NCHRP 8-51 Estimate**	**NCHRP 8-51 Error**	**MTC Survey Estimate**	**MTC Survey Error**	**URBEMIS Estimate**	**URBEMIS Error**
Gateway Oaks, Sacramento	missing	2,858	**na**	2,779	**na**	1,891	**na**	2,379	**na**	2,498	**na**	2,377	**na**
Jamboree Center, Irvine	3,513	4,212	20%	4,096	17%	2,329	-34%	4,283	22%	3,681	5%	3,775	7%
Park Place, Irvine	1,676	3,289	96%	3,230	93%	2,016	20%	2,659	59%	2,874	71%	3,046	82%
The Villages, Irvine	605	877	45%	875	45%	665	10%	750	24%	766	27%	655	8%
Rio Vista Station Village, San Diego	452	757	67%	744	65%	500	11%	432	-4%	419	-7%	459	2%
La Mesa Village Plaza, San Diego	434	518	19%	508	17%	381	-12%	294	-32%	286	-34%	380	-12%
Uptown Center, San Diego	1,560	1,203	-23%	1,148	-26%	1,722	10%	968	-38%	1,051	-33%	899	-42%
The Village at Morena Linda Vista, San Diego	361	774	114%	766	112%	456	26%	445	23%	428	19%	568	57%
Hazard Center, San Diego	978	1,891	93%	1,869	91%	1,231	26%	819	-16%	1,046	7%	1,530	56%
Heritage Center at Otay Ranch, Chula Vista	673	697	4%	656	-3%	980	46%	1,136	69%	609	-9%	1,024	5%
Average error			48%		46%		11%		12%		5%		18%
Average absolute error			54%		54%		22%		32%		24%		30%

Table 11. PM Peak Hour Trip Estimates vs Counts - continued

Infill Site and Location	PM Peak Hour Count	Trip Gen Rates: ITE Rate Estimate	Trip Gen Rates: ITE Rate Error	Candidate Methods: ITE Multi-Use Estimate	ITE Multi-Use Error	EPA MXD Estimate	EPA MXD Error	NCHRP 8-51 Estimate	NCHRP 8-51 Error	MTC Survey Estimate	MTC Survey Error	URBEMIS Estimate	URBEMIS Error
Retail, Oakland	44	41	-7%	**A**	**na**	36	-18%	26	-41%	24	-45%	16	-64%
Office, San Francisco	110	178	61%	**A**	**na**	104	-6%	108	-2%	105	-5%	88	-20%
Office, Los Angeles	84	201	140%	**A**	**na**	**B**	**na**	201	140%	153	82%	81	-3%
Residential, San Diego	36	81	126%	**A**	**na**	47	31%	59	64%	48	33%	50	39%
Residential, San Diego	72	127	76%	**A**	**na**	68	-6%	53	-26%	75	4%	98	36%
Office, Los Angeles	51	135	166%	**A**	**na**	**B**	**na**	127	150%	79	56%	49	-3%
Office, Los Angeles	99	126	28%	**A**	**na**	**B**	**na**	118	20%	96	-3%	45	-54%
Residential, San Diego	33	49	47%	**A**	**na**	**B**	**na**	30	-10%	37	12%	34	2%
Residential, Pasadena	36	44	22%	**A**	**na**	**B**	**na**	37	1%	34	-7%	34	-7%
Residential, San Francisco	29	147	399%	**A**	**na**	47	60%	25	-15%	86	193%	47	60%
Restaurant, San Francisco	13	22	75%	**A**	**na**	20	55%	13	3%	13	3%	14	11%
Restaurant, San Francisco	50	45	-10%	**A**	**na**	40	-20%	26	-47%	26	-47%	27	-46%
Average error			94%				14%		20%		23%		-4%
Average absolute error			96%				28%		43%		41%		29%

A = Method is not applicable to infill sites

B = Missing input data (Employment within 30 min. by transit)

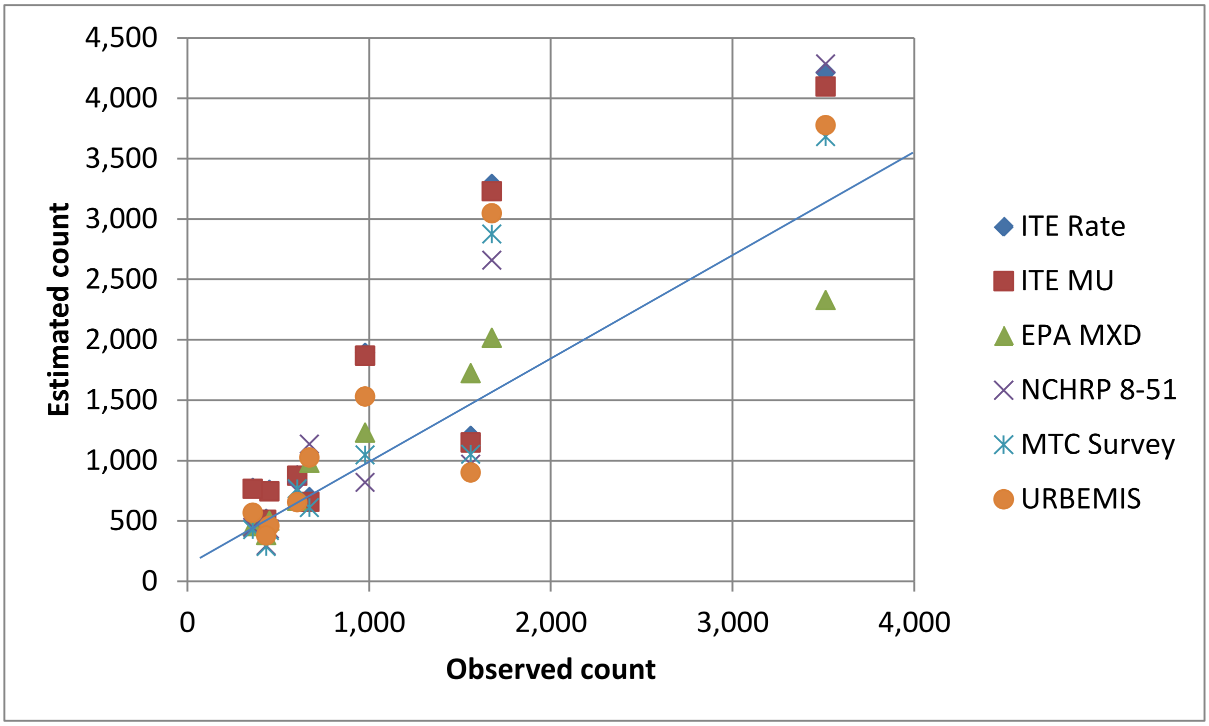

Figure 4a. Estimated versus Observed Count – **PM Peak Hour for Multi-Use Sites**

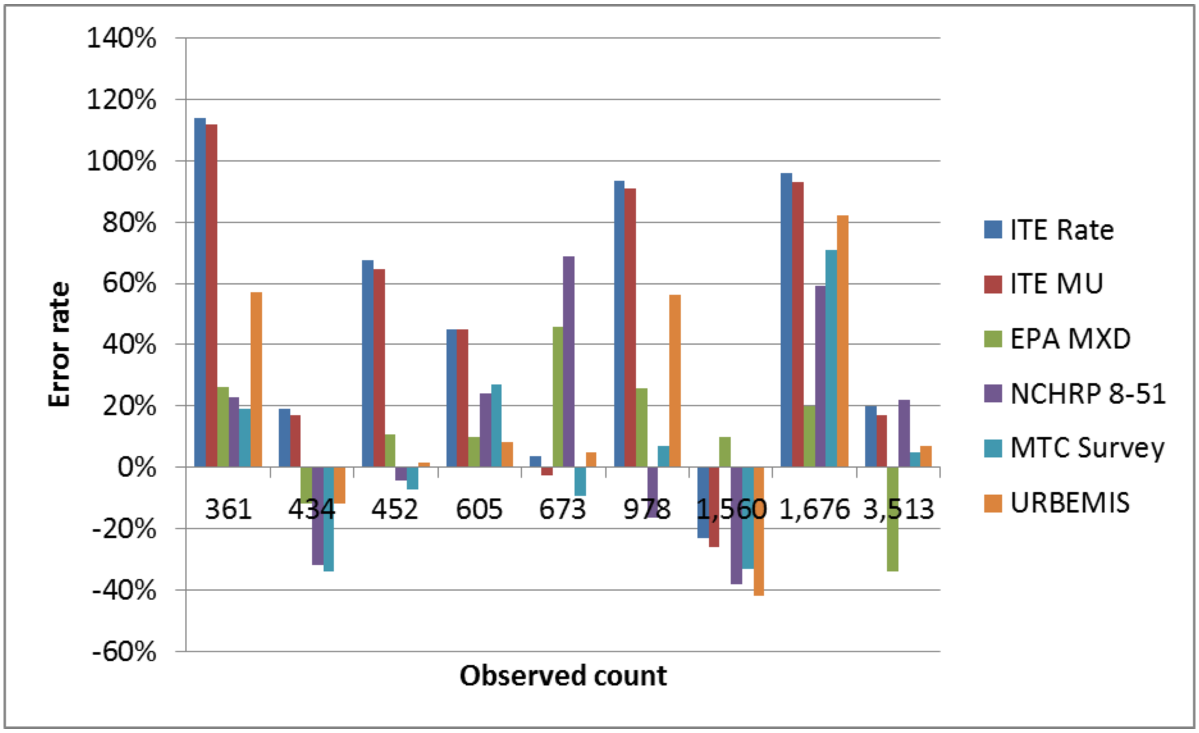

Figure 4b. Error Rate versus Observed Count – **PM Peak Hour for Multi-Use Sites**

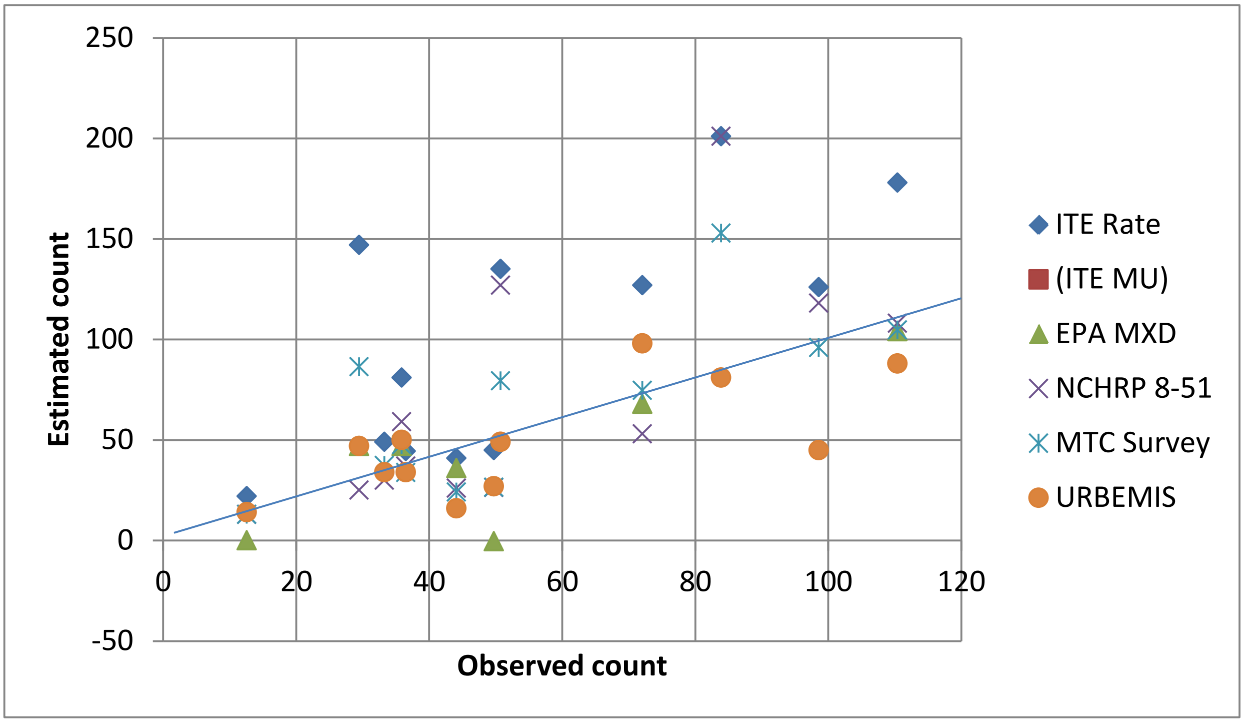

Figure 5a. Estimated versus Observed Count – **PM Peak Hour for Infill Sites**

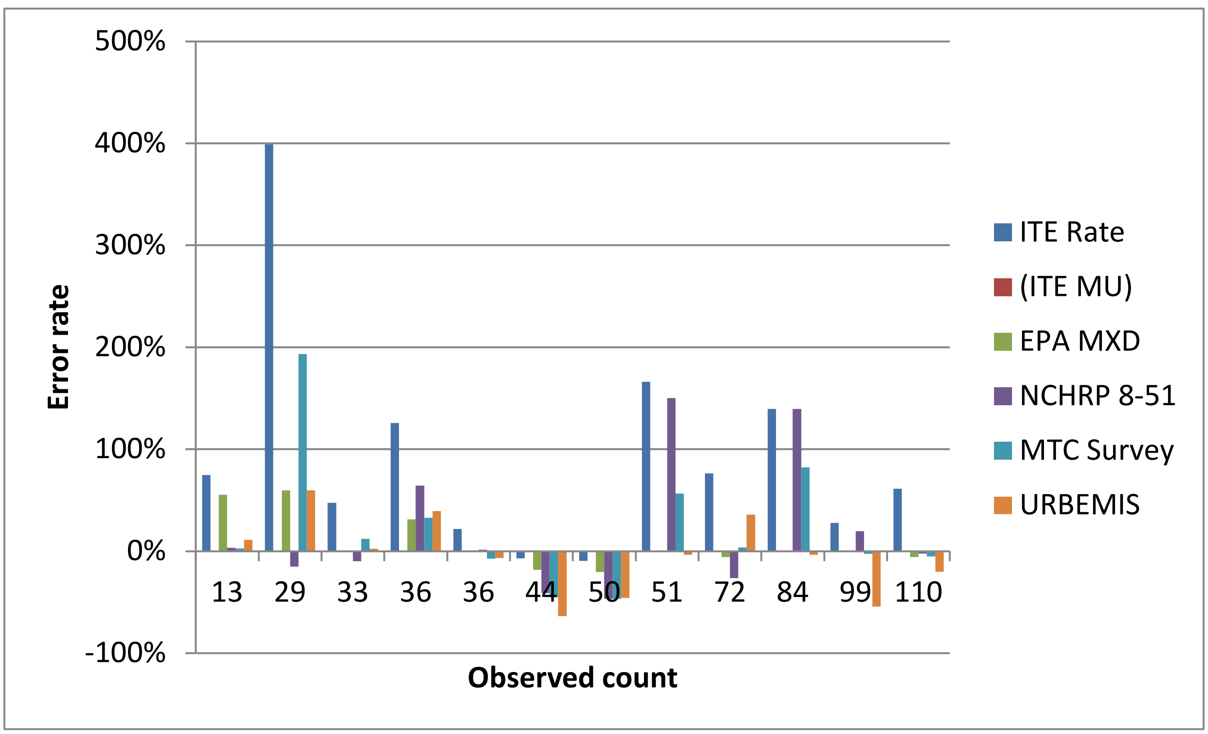

Figure 5b. Error Rate versus Observed Count – **PM Peak Hour for Infill Sites**

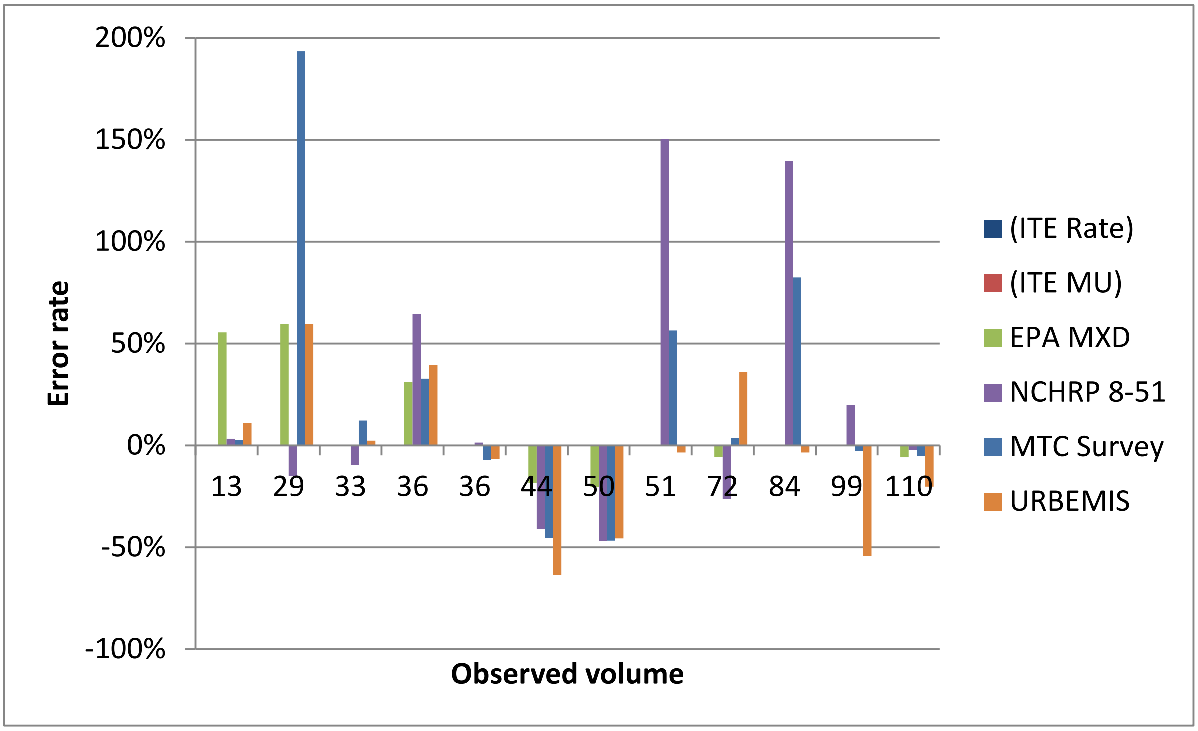

Figure 5c. Error Rate versus Observed Count – **PM Peak Hour for Infill Sites – without ITE Rate Estimates**

4.4 Summary

Table 12 indicates *for each site* the method that most accurately matches the observed traffic counts for the two sets of land use sites. For sites where the raw ITE rate is the best match, the candidate method that mostly closely matches the observed count is also shown.

For the multi-use sites, all of which are large-scale projects not located in the central business district, the EPA MXD method produces the most accurate estimate in the greatest number of sites. For daily counts, the EPA MXD method is most accurate for seven of the sites. Its performance drops to two sites for AM peak hour and four sites for PM peak hour. As noted earlier, it is not surprising that the EPA MXD method is most accurate for the multi-use sites, given that these sites were chosen based on their similarity to the sites used to calibrate the method. The MTC Survey method is most accurate for four multi-use sites for the AM peak hour and three sites for the PM peak hour. URBEMIS is most accurate for two sites for daily counts, two for AM peak hour, and three for PM peak hour. The ITE Multi-use method was most accurate for daily counts for one site and for PM peak hour for one site. The NCHRP 8-51 method was the most accurate for two sites in the AM peak hour (note that this method does not produce estimates of daily counts). ITE trip rates were more accurate than the candidate methods for daily counts for three of the sites.

For the single-use urban infill sites, a clearly best method does not emerge. For the AM peak hour, the methods were most accurate for relatively equal numbers of sites: the EPA/MXD method was most accurate for three sites, the MTC Survey method for two, URBEMIS for four, and the NCHRP method for four. For the PM peak hour, the numbers are roughly equal: the EPA/MXD method was most accurate for three sites, the MTC Survey method for three, URBEMIS for three, and the NCHRP method for four. Across both the AM and PM peak hours, the NCHRP method is most accurate for the greatest number of sites, followed by URBEMIS, the EPA/MXD method, and the MTC Survey method. Note that the ITE Multi-use method was not applied to the infill sites because it requires at least two land uses. ITE trip rates were as or more accurate than the candidate methods in three cases, but were much higher for the other sites.

Table 12. Most Accurate Method for Each Evaluation Site (Showing Method with Lowest Error Rate)

Multi-Use Site and Location	**Daily**	**% Error**	**AM Peak Hour**	**% Error**	**PM Peak Hour**	**% Error**	**Notes on Site**
Gateway Oaks, Sacramento	ITE Multi-Use	0%	na		na		Large site, little use mix
Jamboree Center, Irvine	EPA MXD	-3%	MTC survey	9%	MTC survey	5%	Large site, little use mix
	ITE Rate	*1%*					
Park Place, Irvine	EPA MXD	15%	EPA MXD	23%	EPA MXD	20%	Mulit-use, low-density
	MTC Survey	15%					
The Villages, Irvine	URBEMIS	-7%	MTC survey	0%	URBEMIS	8%	Higher density, lowest WalkScore (40)
Rio Vista Station Village, San Diego	EPA MXD	4%	MTC survey	28%	URBEMIS	2%	Multi-use suburban, LRT
La Mesa Village Plaza, San Diego	EPA MXD	-5%	EPA MXD	10%	EPA MXD	-12%	Multi-use suburban, LRT
	ITE Rate	*-3%*	NCHRP 8-51	-10%	URBEMIS	-12%	
Uptown Center, San Diego	EPA MXD	1%	URBEMIS	3%	EPA MXD	10%	Multi-use urban; no rail
The Village @Morena Linda Vista, San Diego	EPA MXD	11%	MTC survey	22%	MTC survey	19%	Multi-use suburban, LRT
Hazard Center, San Diego	URBEMIS	2%	NCHRP 8-51	11%	MTC survey	7%	Office+retail, LRT no res'l
Heritage Center @ Otay Ranch, Chula Vista	EPA MXD	-20%	URBEMIS	10%	ITE Multi-	-3%	Suburban, no LRT
	ITE Rate	*-13%*					
Infill Study Site and Location							
Retail, Oakland	na		EPA MXD	-92%	EPA MXD	-18%	Retail only, Oakland
			ITE Rate	*-92%*	*ITE Rate*	*-7%*	
Office, San Francisco	na		EPA MXD	-17%	NCHRP 8-51	-2%	Office Only, CBD
Office, Los Angeles	na		URBEMIS	-23%	URBEMIS	-3%	Office Only, CBD
Residential, San Diego	na		MTC Survey	101%	EPA MXD	31%	High–rise res'l, CBD
Residential, San Diego	na		MTC Survey	-6%	MTC Survey	4%	Res'l + coffee shop, CBD
Office, Los Angeles	na		URBEMIS	79%	URBEMIS	-3%	Office Only, CBD
Office, Los Angeles	na		URBEMIS	-25%	MTC Survey	-3%	Office Only, CBD
Residential, San Diego	na		NCHRP 8-51	-7%	URBEMIS	2%	Mid–rise res'l Only, CBD
Residential, Pasadena	na		NCHRP 8-51	-25%	NCHRP 8-51	1%	High–rise res'l Only,
			URBEMIS	-25%			
			ITE Rate	*-12%*			
Residential, San Francisco	na		NCHRP 8-51	-14%	NCHRP 8-51	-15%	High–rise res'l Only, CBD
Restaurant, San Francisco	na		EPA MXD	12%	NCHRP 8-51	3%	Quality restaurant only
					MTC Survey	3%	
Restaurant, San Francisco	na		NCHRP 8-51	24%	EPA MXD	-20%	Quality restaurant only
					ITE Rate	*-10%*	

Finally, a summary of the average percent error across all sites for each method is shown in Table 13 below. This table represents the percent error for each site averaged across all sites and indicates that all five methods are more accurate than ITE rates. At the 10 multi-use sites, EPA MXD was most accurate but it was developed for this purpose (i.e. multi-use sites). At the 12 infill sites, no clear winner exists, but URBEMIS and EPA MXD methods are the most accurate of the five. At the 12 infill sites, the percent standard error is significantly higher compared to the 10 multi-use sites, which were more suburban.

Table 13. Summary Table of Average Percent Error Averaged Across All Sites by Method

Method	10 Multi-Use Sites			12 Infill Sites	
	Daily	AM	PM	AM	PM
ITE Rate	19%	78%	54%	148%	96%
ITE Multi-Use	19%	NA	54%	NA	NA
EPA MXD	11%	27%	22%	80%	28%
NCHRP 8-51	?	29%	32%	79%	43%
MTC Survey	25%	31%	24%	78%	41%
URBEMIS	21%	42%	30%	51%	29%

5. Conclusions

This report provides an assessment of five candidate smart growth trip generation methodologies with respect to their performance regarding operational criteria and their accuracy. The results show that all of the candidate methodologies performed better than the ITE rates, but they do not point to a clear "winner" – one methodology that is clearly superior to the others. Nevertheless, this assessment generated many insights that could guide the selection or development of a recommended methodology. Four options seem feasible:

1. The selection of one of the candidate methods as the recommended method, despite its limitations.
2. The development of a "decision-tree" that would guide the analyst as to what method is most appropriately used for what kinds of development projects in what situations.
3. The modification of one or more of the candidate methods to increase its sensitivity to smart growth qualities and to the California context.
4. The development of an entirely new method using available data sources.

A combination of the second and third options might also be considered. The fourth option is limited by the quantity and quality of available data; given the limited trip generation data collected for smart growth development projects, travel survey data offer the most promise but are generally too sparse spatially to be of much use for this purpose. It would be unfeasible in the near term to develop a method for the U.S. comparable to the UK's TRICs or the New Zealand Trips and Parking Database. These methods require a substantial investment in data collection and considerable time to build a sufficient database of multimodal trip generation data from a large and diverse set of development sites. In the long-term, such an approach would be desirable.

These initial results also point to the critical need for further collection of trip generation data at smart growth sites. Based on only 22 sites, the evaluation presented here is not adequate to fully assess the performance of the available methods. In addition, the validation sites do not reflect the full spectrum of smart growth development projects but instead cluster around two extremes – large multi-use suburban sites, and individual urban infill projects. Data from more sites of more types are needed to better understand the performance of the available methods. Such data, if sufficient in quantity and quality, could be used to modify one of the existing methods or calibrate an entirely new method. In addition, development of an acceptable methodology for obtaining such data potentially could form the basis for a long-term effort to build a multimodal trip generation database for the U.S., similar to those in the U.K. and New Zealand.

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Evaluation of the Operation and Accuracy of Five Available Smart Growth Trip Generation Methodologies

Richard Lee
Josh Miller
Rachel Maiss
Mary Campbell
Kevan Shafizadeh
Deb Niemeier
and Susan Handy
Institute of Transportation Studies
University of California, Davis

with Terry Parker
California Department of Transportation

APPENDIX A:
Key Features and Assumptions of Candidate Methods

September 12, 2011

Appendix A: Key Features and Assumptions of Candidate Methods

Table of Contents

Institute of Transportation Engineers (ITE) *Trip Generation Handbook*
Chapter 7 Multi-Use Method

What it is:

A manual procedure for estimating reductions in “external” vehicle trips due to the “internal capture” of travel among land uses within mixed or multi-use development projects.

Where it is used and who uses it:

The tool was developed for estimating the internal capture at planned multi-use projects composed of at least two of the following three land uses: 1) Office, 2) Residential, and 3) Retail. It was developed for projects with a total floor area of between 100,000 and 2 million square feet. The method is explicitly not applicable to Central Business Districts, Suburban Activity Centers, or specific ITE land use classifications that may include a mix of land uses, e.g.: shopping centers, office park/office building with retail, or a hotel with limited retail/restaurant space.

The ITE Multi-use method is used by planners and engineers throughout the U.S. to analyze multi-use projects for traffic impact studies. Users include consultants performing studies and local government staff reviewing studies. The method has been approved by ITE for use since 2004.

Inputs:

This tool requires the applicable ITE land use codes, sizes, and units for the three land uses covered by the method: Office, Residential and Retail.

Outputs:

The tool provides daily and PM peak hour trips by direction (AM peak hour is not estimated).

How it works:

The method starts with ITE single-use rates and adjusts them down by the percentage of internal capture trips among Office, Residential and Retail land uses in order to estimate "baseline" daily and peak-hour vehicle trips.

Knowledge base:

The internal capture percentages are based on detailed surveys of three multi-use projects in Florida.

References:

ITE Trip Generation Handbook, Chapter 7

Support Documents:

The Trip Generation Handbook is the main reference.

Please see the following page for more detailed information on inputs and outputs (output data is hypothetical):

ITE Handbook - Current Mixed / Multi- Use Method

Project Site Size Limitations — 1. The site should be between 100,000 and 2 million square feet in size.

Step 1: Document Characteristics of Multi-Use Development

	Notes / Instructions
Name of Development	
Description and ITE code of each Land Use	
Size of Each Land Use	use most appropriate units (i.e. DU, ksf, seats…)

Step 2: Select Time Period for Analysis

Select Time Period	weekday Midday, weekday PM, weekday Daily

Step 3: Compute Baseline Trip Generation for Individual Land Uses

If multiple residential uses, compute for each land use individually, then record as single land use on worksheet

Compute Directional Trips	enter/exit using ITE rates	can also use local data on rates and directional trips if available
Record Trip Generation Values		

Step 4: Estimate Anticipated Internal Capture Rate Between Each Pair of Land Uses

Input Local Data on Internal Capture (if available)	Tables 7.1 and 7.2 contain ITE internal capture rates estimated based on a series of studies in Florida--if possible, these rates should be replaced with reliable site-specific data

Steps 5, 6, 7, 8, and 9 have been automated.

Step 5: Estimate "Unconstrained Demand" Volume by Direction

Step 6: Estimate "Balanced Demand" Volume by Direction

Step 7: Estimate Total Internal Trips to/from Multi-Use Development Land Uses

Step 8: Estimate the Total External Trips for Each Land Use

Step 9: Calculate Internal Capture Rate and Total External Trip Gen. for Multi-Use Site

OUTPUTS

SAMPLE:

Project Description (1)	Land Use (2)	ITE Code (3)	Size (4)	Units (5)	Rates (6)				Directional Distribution (7)					
									A.M.		P.M.		Midday	
					Daily	A.M.	P.M.	Midday	Entering	Exiting	Entering	Exiting	Entering	Exiting
Specialty Retail Center	Retail	814	7.20	ksf	44.32	6.84	5.02	0	0.48	0.52	0.56	0.44	0	0
High-Rise Residential Condominium/Townhouse	Residential	232	89.30	DU	4.18	0.34	0.38	0.35	0.17	0.83	0.68	0.32	0.43	0.57
High-Turnover Restaurant	Retail	932	0.00	ksf	127.15	13.53	18.49	14.07	0.52	0.48	0.54	0.46	0.53	0.47
General Office Building	Office	710	13.60	ksf	11.01	1.55	1.49	0	0.88	0.12	0.17	0.83	0	0

	Total Trips				Inbound and Outbound Trips					
					A.M.		P.M.		Midday	
	Daily	A.M.	P.M.	Midday	Entering	Exiting	Entering	Exiting	Entering	Exiting
Specialty Retail Center	319	49	36	0	24	25	20	16	0	0
High-Rise Residential Condominium/Townhouse	373	30	34	31	5	25	23	11	15	19
High-Turnover Restaurant	0	0	0	0	0	0	0	0	0	0
General Office Building	150	21	20	0	18	3	3	17	0	0
TOTAL	*842*	*100*	*90*	*31*	*47*	*53*	*46*	*44*	*15*	*19*
INTERNAL CAPTURE %	11%	0%	11%	0%	0%	0%	11%	11%	0%	0%
INTERNAL TRIPS	89	0	10	0	0	0	5	5	0	0
NET TOTAL	***753***	***100***	***80***	***31***	***47***	***53***	***41***	***39***	***15***	***19***

Validation Analyses - ITE Handbook Multi-Use Method

Input Sources and Assumptions

The ITE Handbook Multi-Use Method (found in Chapter 7 of the ITE *Trip Generation Handbook*, *(2001*) adjusts 8th edition trip generation rates down using internal capture rates between three different land use categories: Office, Residential, and Retail. The method was not applicable for the California Infill sites since these sites were analyzed as single-use sites only. This section details the assumptions, data sources, and analytical processes used to generate ITE Handbook Multi-Use Method estimates of vehicle trips for the ten EPA/SANDAG multi-use sites.

While Gateway Oaks is the only analysis described in detail here, the same assumptions, data sources, and analytical processes were also used for the other sites: Jamboree Center, Park Place, The Villages, Rio Vista Station Village, The Village at Morena Linda Vista, La Mesa Village Plaza, Uptown Center, Hazard Center, and Heritage Center at Otay Ranch.

We began with the categories of land uses specified in the EPA and SANDAG analyses of each project. We then separated land uses for the project into Office, Residential, and Retail and designated land uses that were not Office, Residential, or Retail as "Miscellaneous." Next, we used ITE 8th edition trip generation rates to calculate Daily and PM peak period vehicle trip estimates for each land use. These estimates were then used as inputs to the Multi-Use model to estimate internal vehicle trips based on default (ITE-generated) internal capture rates.

Assumption 1: Since the ITE Handbook Multi-Use method does not provide AM peak internal capture rates, estimates were only calculated for PM Peak and Daily periods.

Assumption 2: Internal capture does not need to be estimated for land use categories other than Office, Retail, and Residential because "Miscellaneous" land uses have negligible internal capture as far as the ITE Handbook Multi-Use methodology is concerned.

Assumption 3: “Retail” includes the following land use categories for these analyses: Specialty Retail Center, Shopping Center, Supermarket, High-Turnover Restaurant, and Fast Food with Drive-Through Window.

The example below shows the inputs used to generate the ITE Handbook Multi-Use analysis for Gateway Oaks in Sacramento.

PROJECT TITLE	Gateway Oaks
PROJECT #:	1
ANALYST:	Josh Miller
DATE:	9/3/2010

TRIP GENERATION

This spreadsheet is intended for estimating trip generation and internal capture for multi-use developments. It uses the information provided in the ITE *Trip Generation Handbook*, 8th Edition.

ID	Project Description (1)	Land Use (2)	ITE Code (3)	Size (4)	Units (5)	Rates (6)				Directional Distribution (7)					
										A.M.		P.M.		Midday	
						Daily	A.M.	P.M.	Midday	Entering	Exiting	Entering	Exiting	Entering	Exiting
A	General Office	Office	710	1,084.00	ksf	11.01	1.55	1.49	0	0.88	0.12	0.17	0.83	0	0
B	Apartment	Residential	220	1,351.00	DU	6.65	0.55	0.67	0.52	0.29	0.71	0.61	0.39	0	0
C	High-Turnover Restaurant	Retail	932	12.00	ksf	127.15	13.53	18.49	14.07	0.52	0.48	0.54	0.46	0.53	0.47
D	Hotel	Misc	310	188.00	Rooms	8.17	0.52	0.61	0.72	0.55	0.45	0.58	0.42	0.56	0.44

Project Description (1)	Total Trips				Inbound and Outbound Trips					
					A.M.		P.M.		Midday	
	Daily	A.M.	P.M.	Midday	Entering	Exiting	Entering	Exiting	Entering	Exiting
General Office	11,935	1,680	1,615	0	1,478	202	275	1,340	0	0
Apartment	8,984	743	905	703	215	528	552	353	0	0
High-Turnover Restaurant	1,526	162	222	169	84	78	120	102	116	104
Hotel	1,536	98	115	135	54	44	67	48	64	51
TOTAL	*23,981*	*2,683*	*2,857*	*1,007*	*1,831*	*852*	*1,014*	*1,843*	*182*	*155*
INTERNAL CAPTURE %	3%	0%	3%	0%	0%	0%	3%	3%	0%	0%
INTERNAL TRIPS	651	0	79	0	0	0	28	51	0	0
NET TOTAL	***23,330***	***2,683***	***2,778***	***1,007***	***1,831***	***852***	***986***	***1,792***	***182***	***155***

SANDAG MXD Version 4.0

What it is:

A spreadsheet tool that calculates adjustments to ITE single-use rates based on land use mix and other user inputs.

Where it is used and who uses it:

The San Diego Association of Governments (SANDAG) approved the tool in June, 2010, as an option for estimating the trip generation of smart growth projects in traffic impact studies in the San Diego region. It is particularly suited to mixed-use projects located in urban areas outside of major downtowns.

Developed and validated for use in the San Diego region, this tool begins with SANDAG single-use trip-generation rates, although other rates can also be used. (SANDAG rates are often used elsewhere in California, and to a more limited extent, elsewhere in the US). The tool is used by planners and engineers analyzing smart growth developments for traffic impact studies. Users include consultants performing studies and local government staff reviewing studies.

Inputs:

The key inputs this model requires include: site area (in acres); number of Intersections per square mile in the vicinity of the project; whether transit (bus or rail) is easily accessed from the site; if the project is in an area characterized by small shops (as in a Central Business District or TOD); employment within one mile of the site; and employment reachable within a 30-minute transit trip.

Outputs:

The tool generates daily and AM/PM peak hour trips by direction. It reduces standard SANDAG rates based on three factors: internal capture (trips that do not leave the project site), external (trips extending beyond the project area) walk/bike trips, and estimated external transit trips. If the tool is used to analyze a single-use site, no internal capture component is calculated.

How it works:

SANDAG trip generation rates used to estimate "baseline" daily and peak hour vehicle trip are adjusted based on a set of three regression models, which are also used in the EPA MXD method, that estimate the probability of internal capture or use of transit or walking.

Knowledge base:

Trip reduction factors, also used in the EPA MXD method, are based on regression analysis of land use and travel survey data for 239 multi-use sites in six metropolitan areas: Boston, Atlanta, Houston, Seattle, Portland and Sacramento.

References:

SANDAG website: http://www.sandag.org/

Support Documents:

Trip Generation for Smart Growth (SANDAG 2010)

Forthcoming Journal of Urban Planning and Development article by Reid Ewing et al.

Please see the following table for more detailed information on inputs and outputs for a hypothetical example project: inputs are generally shown in yellow and blue highlighting:

MXD SANDAG TRIP GENERATION MODEL V4		
Project Site Size Limitations	Between 5 and 300+ acres, max. 5,000 dwelling units (d.u.), max. 3 million sq. ft. of commercial use	
Section 1 - General Site Information - *Example*		
Site Name	Example	
Geographic		**Notes / Instructions**
Developed Area (in acres)	14	Include streets, ROW, parking lots, pocket parks. Do not include open space, vacant lots.
Number of Intersections	4	Counts intersections either within or on the perimeter of the MXD (mixed-use development). Does not count most unsignalized driveways or alleys, but does count major entrances to shopping areas or residential developments.
Is Transit (bus or rail) present within the site or across the street?	Yes	Note: This is only used as a way to "zero" out the probability of external trips if no transit is present.
Land Use - Surrounding Area		
Is the site in a Central Business District or TOD?	No	Answering "Yes" will reduce the HBO ("home-based other") and NHB ("non home-based") trip purpose splits for retail use to those found in smaller stores. The nature of the stores (large vs. small) should be the primary factor in the selection here.
Employment within one mile of the MXD	20,773	Does not include employment within the MXD itself
Employment within a 30 minute Transit Trip (Door-to-door)*	70,207	Includes employment within the MXD itself
*Some possible ways to get this are: **Transit skims from a travel demand model** (most defensible, though not always accurate - check for reasonability!), or **GIS analysis**, or **manual method.** For GIS method, must study the transit lines in or adjacent to the site, determine which stops are close enough (taking access time and average wait time into account), and then look at what's around those stops. Use model TAZ data and best-guess percentage of jobs in those TAZs that are close enough to those stops to be within the 30 minute trip. **Rough approximations** of the percentage of jobs at the city level that are within 1/4 (for rail) to ½ mile (for bus) of transit, coupled with employment projections.		
Site Demographics		
Enter Population Directly?	No	If "No", will apply average HH size factors (in section 2) to dwelling units below
Population		Population will be calculated based on dwelling units below and average HH sizes in section 2.
Average Vehicles Owned per Dwelling Unit	1.80	Census 2000 Summary File 3 may provide block group data for the closest block group to the site (choosing table H44 when it prompts you for a table).

<u>Section 2 - Variable Modeling Parameters</u> - input site specific internalization or use default estimates, which are based on NCHRP 365,*Travel Estimation Techniques for Urban Planning,* W. Martin & N. McGuckin (1998).

<u>Section 3 - Trip Generation</u>

Description, ITE Code, Quantity, and Units for each land use

	Daily	AM Peak Hour		PM Peak Hour
Trips from Land uses not covered above ==>	0	0		0
Jobs in those Land Uses	0			

<u>Outputs</u>: *MXD SANDAG and MXD EPA produce the same types of output, but SANDAG uses its own trip generation rates while EPA uses ITE rates*

	Estimates for AM Peak Hour, PM Peak Hour, and Daily			
(Example: AM Peak Hour)	HBW	HBO	NHB	Total
Number of "Raw" ITE Trips Subject to Model	289	549	69	907
Number of Trips:				
Internal Capture	15	21	3	39
Walking External	10	62	3	75
Transit External	6	16	2	24
Net # of IXXI Vehicle Trips	**259**	**450**	**61**	**770**

Section 3 - Trip Generation Appendix

Below is a listing of land uses that the SANDAG model supports:

NOTE: Occupied units / spaces	**Quantity**	**Units**
Residential		
Estate, Urban or Rural		DU
Single Family Detached		DU
Condominium		DU
Apartment		DU
Mobile Home (Family)		DU
Retail		
Super Regional Shopping Center		ksf
Regional Shopping Center		ksf
Community Shopping Center		ksf
Neighborhood Shopping Center		ksf
Specialty Retail / Strip Commercial		ksf
Supermarket		ksf
Drugstore		ksf
Bank with Drive-Thru		ksf
Discount Store		ksf
Restaurant		
Quality		ksf
Sit-down, High Turnover		ksf
Fast Food (With Drive-thru)		ksf
Fast Food (Without Drive-thru)		ksf
Delicatessen (7 AM - 4 PM)		ksf
Office		
Standard Commercial Office		ksf
Large Commercial Office		ksf
Office Park		ksf
Single Tenant Office		ksf
Corporate Headquarters		ksf
Government (Civic Center)		ksf
Post Office (Community, w/mail drop lane)		ksf
Medical-Dental		ksf
Industrial		
Industrial / Business Park (with commercial)		ksf
Industrial / Business Park (no commercial)		ksf
Industrial Plant		ksf
Manufacturing		ksf
Warehousing		ksf
Storage		ksf
Science Research & Development		ksf
Lodging		
Hotel (w/convention facilities, restaurant)		Occ. Room
Motel		Occ. Room
Resort Hotel		Occ. Room
Misc. Uses		
Movie Theater		screen
Religious Facility		ksf
Gas Station (w/Food Mart and Car Wash)		Pump
Hospital		Bed
Convalescent / Nursing Facility		Bed
Library		ksf
Park (developed with meeting rooms and sports facilities)		acre
Transit Station (Light Rail with Parking)		occupied pkg space
Park & Ride Lot		occupied pkg space
Education		
University		Student
Junior College		Student
High School		Student
Middle / Junior High		Student
Elementary		Student
Day Care		Student

EPA MXD Version 4.0

What it is:

A spreadsheet tool that calculates adjustments to ITE single-use rates based on land use mix and other user inputs. .

Where it is used and who uses it:

The tool was developed under the U.S. Environmental Protection Agency (EPA) to supplant the current Institute of Transportation Engineers (ITE) Multi-use method that is described in the ITE *Trip Generation Handbook*, Chapter 7. It is particularly suited to projects located in urban areas outside of significant Central Business Districts (CBDs). This tool is intended for use by planners and engineers throughout the U.S. for analyzing smart growth developments as a part of traffic impact studies. Users include consultants performing studies and local government staff reviewing studies. The method is still under review by an external panel that includes ITE.

Inputs:

Key inputs required include: site area (in acres); number of Intersections per square mile in the vicinity of the project; whether transit (bus or rail) is easily accessed from the site; if the site is in an area characterized by small shops (as in a Central Business District or TOD); and employment within a 30-minute transit trip from the site.

Outputs:

The tool generates daily and AM/PM peak hour trips by direction. It estimates reductions from standard ITE rates due to three factors: internal capture (trips that do not leave the project site), external (extending past project area) walk/bike trips and estimated external transit trips. If the tool is used to analyze a single-use site, no internal capture component is calculated.

How it works:

ITE trip generation rates used to estimate "baseline" daily and peak hour vehicle trips are adjusted based on a set of three regression models that estimate the probability of internal capture or use of transit or walking/bicycling.

Knowledge base:

Trip reduction factors are based on regression analysis of land use and travel survey data for 239 multi-use sites in six metropolitan areas: Boston, Atlanta, Houston, Seattle, Portland and Sacramento.

References:

User guide formatted as an update to the ITE *Trip Generation Handbook.*

Support Documents:

Research Summary (not published; available on the Practitioner Panel list-serve).

Forthcoming *Journal of Urban Planning and Development* article by Reid Ewing et al

Please see the following table for more detailed information on inputs and outputs for a hypothetical example project. Inputs are generally shown in yellow and blue highlighting:

Project Site Size Limitations	Between 5 and 300+ acres, max. 5,000 dwelling units (d.u.), max. 3 million sq. ft. of commercial use		
Section 1 - General Site Information - *Example*			
Site Name	Example		
Geographic		**Notes / Instructions**	
Developed Area (in acres)	14	Include streets, ROW, parking lots, pocket parks. Do not include open space, vacant lots.	
Number of Intersections	294	Counts intersections either within or on the perimeter of the MXD (mixed-use development). Does not count most unsignalized driveways or alleys, but does count major entrances to shopping areas or residential developments.	
Is Transit (bus or rail) present within the site or across the street?	Yes	Note: This is only used as a way to "zero" out the probability of external trips if no transit is present.	
Land Use - Surrounding Area			
Is the site in a Central Business District or TOD?	No	Answering "Yes" will reduce the HBO ("home-based other") and NHB ("non home-based") trip purpose splits for retail use to those found in smaller stores. The nature of the stores (large vs. small) should be the primary factor in the selection here.	
Employment within one mile of the MXD	20,773	Does not include employment within the MXD itself	
Employment within a 30-minute Transit Trip (Door-to-door)*	70,207	Also includes employment within the MXD itself	
*Some possible ways to get this are: **Transit skims from a travel demand model** (most defensible, though not always accurate - check for reasonability!), or **GIS analysis**, or **manual method.** For GIS method, must study the transit lines in or adjacent to the site, determine which stops are close enough (taking access time and average wait time into account), and then look at what's around those stops. Use model TAZ data and best-guess percentage of jobs in those TAZs that are close enough to those stops to be within the 30-minute trip. **Rough approximations** of the percentage of jobs at the city level that are within 1/4 (for rail) to ½ mile (for bus) of transit, coupled with employment projections.			
Site Demographics			
Enter Population Directly?	No	If "No", will apply average HH size factors (in section 2) to dwelling units below	
Population		Population is automatically calculated based on dwelling units below and average HH sizes in section 2.	
Average Vehicles Owned per Dwelling Unit	1.80	Census 2000 Summary File 3 block group data may provide data for the closest block group to the site (choosing table H44 when it prompts for a table). Or use default estimates, which are based on NCHRP 365,*Travel Estimation Techniques for Urban Planning,* W. Martin & N. McGuckin (1998)	
Section 2 - Variable Modeling Parameters – requires site-specific internalization rates, or the use default estimates based on NCHRP 365,*Travel Estimation Techniques for Urban Planning, W. Martin & N. McGuckin (1998)*			
Section 3 - Trip Generation			
Description, ITE Code, Quantity, and Units for each land use			
	Daily	AM Peak Hour	PM Peak Hour
Trips from Land uses not covered above ==>	0	0	0
Jobs in those Land Uses	0		
Outputs: ***MXD SANDAG and MXD EPA methodologies produce the same types of output, but the SANDAG MXD methodology uses SANDAG's trip generation rates, while the EPA MXD methodology uses ITE rates***			
	Estimates for AM Peak Hour, PM Peak Hour, and Daily		

(Example: AM Peak Hour)	HBW	HBO	NHB	Total
Number of "Raw" ITE Trips Subject to Model	289	549	69	907
Number of Trips:				
Internal Capture	15	21	3	39
Walking External	10	62	3	75
Transit External	6	16	2	24
Net # of IXXI Vehicle Trips	**259**	**450**	**61**	**770**

Validation Analyses – EPA & SANDAG MXD Methods

Input Sources and Assumptions:

The EPA/SANDAG MXD method requires a moderate amount of site-specific data. The accuracy of this model depends on the availability of the inputs. Most input data can be obtained from site plans and aerial photography, while demographic data and needed information on surrounding employment can be obtained from either regional agencies or the Census. The method was applied to the 10 EPA/SANDAG multi-use sites and the 12 California infill sites.

Base Vehicle-Trip Generation Estimates for the 10 EPA/SANDAG Sites:

ITE Trip Generation (8th edition) equations were used to estimate baseline peak hour directional vehicle trips for Gateway Oaks, Jamboree Center, Park Place, and The Villages. SANDAG *Traffic Generators* rates were used to generate baseline trip estimates at Rio Vista Station Village, La Mesa Village Plaza, Uptown Center, Hazard Center, and Heritage Center at Otay Ranch.

Key Input Data Sources and Assumptions for all sites:

Data or Assumption	***EPA/SANDAG Sites***	***Infill Sites***
Area (in acres) & Number of Intersections	Calculated from site plan and aerial photographs	U.S. Census Bureau's LED OnTheMap, assumed intersection density within site equal to intersection density in the surrounding area
Whether Transit (bus or rail) present at site	Based on current transit maps	Based on current transit maps
Whether the site in a Central Business District or TOD[1]	Aerial photographs (Google Earth)	Aerial photographs (Google Earth)
Employment within one mile of the MXD	Census data using GIS	U.S. Census Bureau's LED OnTheMap
Employment within a 30-minute Transit Trip	MPO model skims	MTC and SANDAG model skims (SCAG skims not available as of 10-12-10
Household size (where applicable)	MPO data or Census data for the closest block group	Default values (based on national averages)
Vehicles Owned per Dwelling Unit	MPO data or Census 2000 Summary File 3 block group data for the closest block group to the site	Census 2000 data (total block group vehicles divided by total dwelling units)
Basic Trip Rates	SANDAG trip rates and ITE Trip Generation 8th Edition equations	ITE Trip Generation 8th Edition average rates

This example shows the inputs used to generate the analysis for San Diego's Uptown Center:

Section 1 - General Site Information				
Site Name:				Uptown Center
Geographic				
Area (in acres)				14.13
Number of Street Intersections				4
Is Transit (bus or rail) present within the site?				Yes
Land Use - Surrounding Area				
Is the site in a Central Business District or Transit Oriented Development?				No
Employment within one mile of the site (number of jobs)				15,722
Employment within a 30-minute transit trip of site				271,368
Site Demographics				
Population - Enter Directly?				No
("No" means default values of Population and Employment ratios are used)				
Average Vehicles Owned per Dwelling Unit				1.35
Average Household Size		*Default Values:*		**Source:**
	Estate, Urban or Rural	3.2		Default Value
	Single Family Detached	3.2		Default Value
	Condominium	1.56		SANDAG Database
	Apartment	1.56		SANDAG Database
	Mobile Home (Family)	2.5		Default Value

National Cooperative Highway Research Program (NCHRP) 8-51 Multi-Use Method

What it is:

A spreadsheet tool for estimating reductions in external vehicle trips due to internal capture of travel among land uses at mixed or multi-use development projects.

Where it is used and who uses it:

The tool was developed for estimating “internal capture” (e.g., trips that do not leave a project) at planned multi-use projects that have: two or more revenue-producing land uses; internal pedestrian and vehicular connectivity; and shared parking among some or all uses. This method was developed for projects with at least 100,000 square feet of building space and overall size of up to 300 acres. Since it may supplant the current Institute of Transportation Engineers (ITE) Trip Generation Handbook multi-use methodology, the ITE limitations on development type should presumably also apply: e.g., it should not be applied to projects located within Central Business Districts, Suburban Activity Centers, or ITE land use classifications with the potential for a mix of land uses, such as shopping centers, office park/office building with retail, or a hotel with limited retail/restaurant space. Though the NCHRP 08-51 method is still under review, it is expected to be available by the end of 2010 for use in transportation impact analyses of multi/mixed use developments.

Inputs:

Key inputs for this method include the number and quantity of the seven land uses covered by the method: Office, Retail, Restaurant, Cinema/Entertainment, Residential, Hotel, and All Other Land Uses. For these land use categories, the spreadsheet tool requires Total, Entering, and Exiting trips (calculated from existing ITE rates). In addition, the tool requires local estimates of mode split and vehicle occupancy. For the PM peak hour estimate, users are asked to provide average walking distances between select land uses.

Outputs:

AM and PM peak hour trips by direction (Daily trips are not estimated). Please see the following page for more detailed information on Inputs and outputs.

How it works:

ITE trip generation rates are used to estimate directional peak hour vehicle trips (e.g., # of vehicles entering and exiting the boundaries of a land use project during peak morning and evening travel times). The model adjusts these estimates using "Adjusted Internal Capture Rates" in Tables 7.1a and 7.2a. These tables are essentially the Internal Capture Rate tables 7.1 and 7.2 from the ITE Handbook with added rates for trips between Cinema/Entertainment, Restaurant, Hotel, and other land uses. For PM peak hour estimates, these internal capture rates are adjusted for average walking distances between select land uses; there was insufficient data to allow this option for the AM Peak hour.

Knowledge base:

The adjusted internal capture percentages among uses is based on detailed data collected at three multi/mixed-use sites (two in Texas, one in Georgia) conducted for the NCHRP 8-51 study, as well as data from a prior study in Florida.

References:

NCHRP 8-51 Internal Trip Capture Estimator Version 8 062810 (to be published).

Support Documents:

Draft Final NCHRP 8-51 report: Revised Phase 1 Methodology July 2010 (not publicly available).

Detailed information on Inputs and outputs (Example data is for Gateway Oaks project in Sacramento):

NCHRP 8-51 Use Method

Project Site Size Limitations:
The site should be between 100,00 square feet and 300 acres (based on study and validation sites)

Land Use Information

Notes / Instructions

Name of Development
Land Use Codes, Descriptions, Quantity, and Units

Entering, Exiting, Total according to ITE rates

Directional Trips
SAMPLE:

Table 1-A: Base Vehicle-Trip Generation Estimates (Single-Use Site Estimate)

Land Use	Development Data (*For Information Only*)			Estimated Vehicle-Trips		
	ITE LUCs[1]	Quantity	Units	Total	Entering	Exiting
Office	710	1,084.30	ksf	1681	1,479	202
Retail			ksf		0	0
Restaurant	932	12.00	ksf	162	84	78
Cinema/Entertainment					0	0
Residential	220	1,351.00	DU	743	215	528
Hotel	310	188.00	rooms	98	54	44
All Other Land Uses[2]				0		
Total				2684	1832	852

Table 2-A: Mode Split and Vehicle Occupancy Estimates

Land Use	Entering Trips			Exiting Trips		
	Veh. Occ.	% Transit	% Non-Motorized	Veh. Occ.	% Transit	% Non-Motorized
Office	1.06	7.24%	3.44%	1.06	7.24%	3.44%
Retail	1.33	0.69%	9.30%	1.33	0.69%	9.30%
Restaurant	1.33	0.69%	9.30%	1.33	0.69%	9.30%
Cinema/Entertainment	1.72	1.89%	6.97%	1.72	1.89%	6.97%
Residential	1.33	0.69%	9.30%	1.33	0.69%	9.30%
Hotel	1.72	1.89%	6.97%	1.72	1.89%	6.97%
All Other Land Uses[2]	1.33	0.69%	9.30%	1.33	0.69%	9.30%

Note by project team: Vehicle trips are computed using mode split and vehicle occupancy data above. This data is particularly hard to find, and it is the greatest challenge to using this method. For PM trips, tool requires Table 3-A: Average Land Use Interchange Distances (ft. walking distance) between uses.

Outputs*

Table 5-A: Computations Summary			
	Total	Entering	Exiting
All Person-Trips	3,161	2,063	1,098
Internal Capture Percentage	4%	3%	6%
External Vehicle-Trips[3]	2,307	1,588	719
External Transit-Trips[4]	137	117	20
External Non-Motorized Trips[4]	176	93	83

Table 6-A: Internal Trip Capture Percentages by Land Use		
Land Use	Entering Trips	Exiting Trips
Office	2%	8%
Retail	N/A	N/A
Restaurant	23%	38%
Cinema/Entertainment	N/A	N/A
Residential	2%	1%
Hotel	3%	5%

*These outputs can only be calculated for Peak AM and Peak PM time periods.

Validation Analyses - NCHRP 8-51 Method

Input Sources and Assumptions - 10 EPA/SANDAG Multi-Use Sites

The Internal Trip Capture Estimation Tool for Mixed-Use Developments (referred to as NCHRP 8-51) is a spreadsheet tool that requires a relatively small set of site-specific data compared to URBEMIS. Because it has relatively few inputs, the accuracy of this model depends substantially on the accuracy of this data, particularly data on the mode split of trips to and from the site. This section details the assumptions, data sources, and analytical processes used to generate NCHRP 8-51 estimates of vehicle trips for ten EPA/SANDAG multi-use sites. While Morena Linda Vista is the only analysis described in detail here, the same assumptions, data sources, and analytical processes were also used for the remaining sites: Gateway Oaks, Jamboree Center, Park Place, The Villages, Rio Vista Station Village, La Mesa Village Plaza, Uptown Center, Hazard Center, and Heritage Center at Otay Ranch.

Table 1-A/P: Base Vehicle-Trip Generation Estimates: Tables 1-A and 1-P are the input cells of the spreadsheet for basic trip generation data in the AM and PM peak hours respectively. In accordance with NCHRP 8-51 recommendations, ITE 8th edition trip generation rates were used to estimate peak hour directional trips for each of the land use categories.

Table 2-A and 2-P: Mode Split and Vehicle Occupancy Estimates: NCHRP 8-51 recommends the use of peak hour, directional mode split and vehicle occupancy data collected from sites with similar characteristics. Because this data was not available, detailed daily mode split and vehicle occupancy data from the San Francisco region's Metropolitan Transportation Commission (MTC) were used. However, no other California regional planning agency provided such data for this analysis.

The following three assumptions were made at each EPA/SANDAG multi-use site for mode split in Tables 2-A and 2-P:

Assumption 1: MTC daily mode split data[1] collected in the Bay Area are suitable for use as peak hour data for smart growth sites in California. This mode split data was used to estimate mode split at the ten EPA/SANDAG sites as no local data was available. Since the Bay Area has a higher mode split for transit and walking than the remainder of California, this assumption may bias estimates of vehicles downward at these sites. However, smart growth sites outside of the Bay Area are likely to have mode splits closer to those of the Bay Area than do conventional developments.

Assumption 2: MTC mode split and vehicle occupancy data for various site categories is suitable for sites outside the Bay Area with similar characteristics. MTC has separate mode split and vehicle occupancy data for the following categories: within 1/2 mile of rail station (or ferry terminal), within 1/2 mile to 1 mile of rail station, and greater than 1 mile from rail station. The MTC separates the "greater than 1 mile" category into Urban, High-Suburban, Low-Suburban, and Rural.

Assumption 3: The same set of mode split and vehicle occupancy data can be applied to both entering and exiting trips.

Table 3-P: Average Land Use Interchange Distances: These represent walking distances between uses on the site. These inputs are specific to PM peak hour vehicle trip estimation. Due to the limited site-specific data available, we computed PM peak hour trips without inputting average land use interchange distances.

Assumption 4: PM peak hour vehicle trip estimates calculated without interchange distances are still indicative of the model's overall performance. Test runs were conducted using an interchange distance based on half the length of the site. For the three largest sites over 100 acres (Gateway Oaks, Jamboree Center and Park Place), this results in average walking distances of nearly a half-mile or more among some land uses within the site. Such distances would result in less internal capture, and an estimated 4-7 percent increase in external vehicle trips at these sites (which would in turn reduce the accuracy of the estimates compared to available ground counts). For smaller sites (e.g. the six San Diego sites which are all 16 acres or smaller), including the interchange distances has a negligible effect on the PM peak hour estimates.

Input Sources and Assumptions - 12 California Infill Study Sites

Assumptions 3 and 4 above for the EPA/SANDAG sites were also applied to the twelve selected California Infill study sites. Since these are very small sites (generally one building), and because these were treated as single-use sites, the Average Land Use Interchange Distances criteria do not apply.

Table 1-A/P: Base Vehicle-Trip Generation Estimates: The ITE 8th edition trip generation rates specified for each site in the CA Infill Study report were used.

Table 2-A/P: Mode Split and Vehicle Occupancy Estimates: We used the actual mode splits obtained via intercept surveys provided for each site in the Infill Study report.

The example below shows the inputs used to generate the NCHRP 8-51 analysis for Morena Linda Vista, a multi-use site located in San Diego.

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[1]Data Source: MTC StaRS Appendix E Tables (in Volume 2): http://www.mtc.ca.gov/planning/smart_growth/stars/

NCHRP 8-51 Internal Trip Capture Estimation Tool			
Project Name:	Morena Linda Vista	**Organization:**	UCD
Project Location:	San Diego, CA	**Performed By:**	Josh Miller
Scenario Description:		**Date:**	9/2/2010
Analysis Year:		**Checked By:**	
Analysis Period:	AM Street Peak Hour	**Date:**	

Table 1-A: Base Vehicle-Trip Generation Estimates (Single-Use Site Estimate)

Land Use	Development Data (*For Information Only*)			Estimated Vehicle-Trips		
	ITE LUCs[1]	Quantity	Units	Total	Entering	Exiting
Office	710		ksf	0	0	0
Retail	814	8.00	ksf	40	22	18
Restaurant			ksf	397	212	185
Cinema/Entertainment	710			0	0	0
Residential	220	176.00	DU	118	72	46
Hotel	310		rooms	0	0	0
All Other Land Uses[2]	93	165.00		219	127	92
Total				774	433	341

Table 2-A: Mode Split and Vehicle Occupancy Estimates

Land Use	Entering Trips			Exiting Trips		
	Veh. Occ.	% Transit	% Non-Motorized	Veh. Occ.	% Transit	% Non-Motorized
Office	1.15	29.42%	16.14%	1.15	29.42%	16.14%
Retail	1.34	13.40%	21.98%	1.34	13.40%	21.98%
Restaurant	1.34	13.40%	21.98%	1.34	13.40%	21.98%
Cinema/Entertainment	1.77	13.94%	28.82%	1.77	13.94%	28.82%
Residential	1.34	13.40%	21.98%	1.34	13.40%	21.98%
Hotel	1.77	13.94%	28.82%	1.77	13.94%	28.82%
All Other Land Uses[2]	1.34	13.40%	21.98%	1.34	13.40%	21.98%

Table 3-A: Average Land Use Interchange Distances (Feet Walking Distance)

Origin (From)	Destination (To)					
	Office	Retail	Restaurant	Cinema/Entertainment	Residential	Hotel
Office						
Retail						
Restaurant						
Cinema/Entertainment						
Residential						
Hotel						

Table 4-A: Internal Person-Trip Origin-Destination Matrix*

Origin (From)	Destination (To)					
	Office	Retail	Restaurant	Cinema/Entertainment	Residential	Hotel
Office		0	0	0	0	0
Retail	0		3	0	3	0
Restaurant	0	15		0	10	0
Cinema/Entertainment	0	0	0		0	0
Residential	0	1	12	0		0
Hotel	0	0	0	0	0	

Table 5-A: Computations Summary

	Total	Entering	Exiting
All Person-Trips	1,034	578	456
Internal Capture Percentage	9%	8%	10%
External Vehicle-Trips[3]	456	257	199
External Transit-Trips[4]	127	72	55
External Non-Motorized Trips[4]	208	117	91

Table 6-A: Internal Trip Capture Percentages by Land Use

Land Use	Entering Trips	Exiting Trips
Office	N/A	N/A
Retail	55%	25%
Restaurant	5%	10%
Cinema/Entertainment	N/A	N/A
Residential	14%	21%
Hotel	N/A	N/A

[1]Land Use Codes (LUCs) from *Trip Generation Informational Report*, published by the Institute of Transportation Engineers.
[2]Total estimate for all other land uses at mixed-use development site-not subject to internal trip capture computations in this estimator
[3]Vehicle-trips computed using the mode split and vehicle occupancy values provided in Table 2-A
[4]Person-Trips
*Indicates computation that has been rounded to the nearest whole number.

Estimation Tool Developed by the Texas Transportation Institute

NCHRP 8-51 Internal Trip Capture Estimation Tool

Project Name:	Morena Linda Vista	Organization:	UCD
Project Location:	San Diego, CA	Performed By:	Josh Miller
Scenario Description:		Date:	9/2/2010
Analysis Year:		Checked By:	
Analysis Period:	PM Street Peak Hour	Date:	

Table 1-P: Base Vehicle-Trip Generation Estimates (Single-Use Site Estimate)

Land Use	Development Data (*For Information Only*)			Estimated Vehicle-Trips		
	ITE LUCs[1]	Quantity	Units	Total	Entering	Exiting
Office				0	0	0
Retail	814	8.00	ksf	54	26	28
Restaurant				354	182	172
Cinema/Entertainment				0	0	0
Residential	220	176.00	DU	97	28	69
Hotel				0	0	0
All Other Land Uses[2]	93	165.00		188	150	38
Total				693	386	307

Table 2-P: Mode Split and Vehicle Occupancy Estimates

Land Use	Entering Trips			Exiting Trips		
	Veh. Occ.	% Transit	% Non-Motorized	Veh. Occ.	% Transit	% Non-Motorized
Office	1.15	29.42%	16.14%	1.15	29.42%	16.14%
Retail	1.34	13.40%	21.98%	1.34	13.40%	21.98%
Restaurant	1.34	13.40%	21.98%	1.34	13.40%	21.98%
Cinema/Entertainment	1.77	13.94%	28.82%	1.77	13.94%	28.82%
Residential	1.34	13.40%	21.98%	1.34	13.40%	21.98%
Hotel	1.77	13.94%	28.82%	1.77	13.94%	28.82%
All Other Land Uses[2]	1.34	13.40%	21.98%	1.34	13.40%	21.98%

Table 3-P: Average Land Use Interchange Distances (Feet Walking Distance)

Origin (From)	Destination (To)					
	Office	Retail	Restaurant	Cinema/Entertainment	Residential	Hotel
Office						
Retail						
Restaurant						
Cinema/Entertainment						
Residential						
Hotel						

Table 4-P: Internal Person-Trip Origin-Destination Matrix*

Origin (From)	Destination (To)					
	Office	Retail	Restaurant	Cinema/Entertainment	Residential	Hotel
Office		0	0	0	0	0
Retail	0		11	0	4	0
Restaurant	0	10		0	5	0
Cinema/Entertainment	0	0	0		0	0
Residential	0	16	19	0		0
Hotel	0	0	0	0	0	

Table 5-P: Computations Summary

	Total	Entering	Exiting
All Person-Trips	926	516	410
Internal Capture Percentage	14%	13%	16%
External Vehicle-Trips[3]	382	216	166
External Transit-Trips[4]	108	61	47
External Non-Motorized Trips[4]	175	99	76

Table 6-P: Internal Trip Capture Percentages by Land Use

Land Use	Entering Trips	Exiting Trips
Office	N/A	N/A
Retail	74%	41%
Restaurant	12%	7%
Cinema/Entertainment	N/A	N/A
Residential	24%	36%
Hotel	N/A	N/A

[1]Land Use Codes (LUCs) from *Trip Generation Informational Report*, published by the Institute of Transportation Engineers.

[2]Total estimate for all other land uses at mixed-use development site-not subject to internal trip capture computations in this estimator

[3]Vehicle-trips computed using the mode split and vehicle occupancy values provided in Table 2-P

[4]Person-Trips

*Indicates computation that has been rounded to the nearest whole number.

Estimation Tool Developed by the Texas Transportation Institute

URBEMIS 2007 (version 9.2.4)

What it is:

A software tool compatible with Windows operating systems that estimates vehicle trips and associated air emissions based on user-specified inputs and selected mitigation measures.

Where it is used and who uses it:

URBEMIS (which stands for "urban emissions") is commonly used to estimate air quality emissions, including greenhouse gas (GHG), associated with proposed land use development projects in California. URBEMIS was originally developed by the California Air Resources Board (CARB) in the 1980s. Since the late 1990s, it has been supported and expanded by a consortium of air quality management districts throughout California. URBEMIS is used in California for compliance with the California Environmental Quality Act (CEQA), which requires assessment of air quality emissions for significant proposed land use projects. Also, some air quality management districts in California require the use of URBEMIS as part of their Indirect Source Rules. This tool is also used by some consultants to estimate trip generation for traffic impact analyses of proposed land use development projects.

Inputs:

Estimating "unmitigated" operational vehicle trips requires only inputting the amount and size of various land uses in a project by ITE land use classification. It also includes a set of motor vehicle "operational mitigation measures" that can be specified to estimate reductions in daily and yearly vehicle trips, VMT, and associated emissions for several land use and transportation strategies. Depending on the number of operational mitigation measures the user selects, URBEMIS input data requirements can be significant.

Outputs:

URBEMIS provides detailed information on air pollution and GHG emissions. It also provides vehicle miles travelled (VMT) and vehicle trips both *with* and *without* selected operational mitigation measures for each project. However, URBEMIS does not provide mode split or AM/PM peak hour trips.

What it is used for and how it works:

URBEMIS currently uses the Institute for Transportation Engineers (ITE) 7th Edition *Trip Generation* rates[2] data to allow users to estimate "baseline" total daily vehicle trips and associated vehicle-related emissions for a variety of land use classifications. For mobile source emissions, URBEMIS uses updated California vehicle emission rates provided by CARB. Operational mitigation measures available in URBEMIS are of two types: 1) Physical (e.g., # of buses within 1/4 mile of center of site, % of arterials with bike lanes or direct parallel routes, # of housing units within 1/2 mile of center, etc. which can be measured from site plans and maps), and 2) Demand Management (such as parking cash-out and provision of free transit passes), which requires information from site managers. *Please see the following pages for more detailed information on motor vehicle operational mitigation measures, inputs, and outputs.*

Knowledge base:

[2] The 8th Edition (2008) is the latest version of ITE Trip Generation.

This version of URBEMIS uses ITE (7th Edition) rates with EMFAC 2007 input files. Percent reduction formulas for operational mitigation measures are derived from a number of research sources, which are well described and documented in the User's Manual (available via the website).

References:

Official website: http://urbemis.com/

Support Documents:

URBEMIS9 Users Manual Main Body.pdf and URBEMIS9 Users Manual Appendices.pdf

Below is a table from URBEMIS9 Users Manual Appendices.pdf *that summarizes the maximum reductions to ITE rates from operational mitigation measures available in URBEMIS software:*

Figure D-3. Summary of Recommended Trip Reductions

	Residential	Non-Residential	Comments
Physical Measures			
Net Residential Density	Up to 55%	N/A	
Mix of Uses	Up to 9%	Up to 9%	
Local-Serving Retail	2%	2%	
Transit Service	Up to 15%	Up to 15%	
Pedestrian/Bicycle Friendliness	Up to 9%	Up to 9%	
Physical Measures sub-total	*Up to 90%*	*Up to 35%*	
Demand Management and Similar Measures			
Affordable Housing	Up to 4%	N/A	
Parking Supply	N/A	No limit	Only if greater than sum of other trip reduction measures
Parking Pricing/Cash Out	N/A	Up to 25%	
Free Transit Passes	25% * reduction for transit service	25% * reduction for transit service	
Telecommuting	N/A	No limit	Not additive with other trip reduction measures (see text)
Other TDM Programs	N/A	Up to 2%, plus 10% of the credit for transit and ped/bike friendliness	
Demand Management sub-total[3]	*Up to 7.75%*	*Up to 31.65%*	

(Note: Net Residential Density is a component of the Mix of Uses measure.)

Detailed Description of Methodology:

URBEMIS 2007 9.2.4			
*(yellow background denotes model **inputs)***		*(green background denotes model **output)***	
Project Site Size Limitations: For use in analyzing proposed land use development projects; not recommended for entire jurisdictions. (note: Developments that are larger than 0.5 miles across must be broken into smaller pieces for the purposes of determining the transit service index. The average of all units would then be used.)			
Project and Operational Mitigation Information			
Site Name			
Geographic			**Notes / Instructions**
Air District/County	e.g. Sacramento		Some areas of California do not have EMFAC files; in these cases, users may select "Statewide."
Operational Emission Sources	**Pass-by Trips**	Yes/No	Other MXD (mixed-use development) methods do not adjust for pass-by trips, so recommended "No."
	Double-Counting Correction		Intended to prevent double-counting of internal trips, since internal trips are excluded from trip estimate already, so recommended "No."
Operational Mitigations Selected and Data Inputs			For mitigations, input data is only required for the measures which are selected
Mix of Uses	# of housing units within 1/2 mile radius, includes the # of units in development		Can be **difficult** to obtain, and model is highly sensitive to this variable. Manual approach involves estimating % of census block groups that 1/2 mile radius covers. This variable may be problematic unless the user finds a reliable way to accurately estimate it.
	Employment within 1/2 mile radius		One source for this figure is the Census Bureau's LED OnTheMap, which is available online at: http://lehdmap4.did.census.gov.
Local Serving Retail	Presence of local serving retail (e.g., grocery store, pharmacy, hardware store, dry cleaners, corner store, café, stationary store, gym, etc.)	Yes/No	
Transit Services	# of daily weekday buses stopping w/in 1/4 mile of site		These may have to be manually counted using Google earth or a GIS application to identify stops within 1/4 (for bus) and 1/2 (for rail) mile radius of the center of the site, as well as the website of the local transit authority to obtain schedule counts.
	# of daily rail or rapid transit buses stopping w/in 1/2 mile of site		
	# of dedicated daily shuttle trips		
Bike and Pedestrians	# of intersections per square mile		Can be obtained manually by counting "valences" intersections for the project or in the project vicinity. within MXD and dividing by

			acreage/640.
	Percent of streets within 1/2 mile with sidewalks on one side	(%)	
	Percent of streets within 1/2 mile with sidewalks on both sides	(%)	
	Percent of arterials/collectors with bike lanes (or where suitable, direct parallel routes exist)	(%)	
Affordable Housing	% of units dedicated to low-income housing	(%)	
Transportation Demand Measures			
Parking, Transit Passes			
	Daily Parking Charge		Yes/No
	Free Transit Passes		Yes/No
	Parking Price (nonresidential)		$
Telecommuting			% participating
Employee Telecommuting Program		Yes/No	(%), Avg. days/week
Compressed work schedule 3/36		Yes/No	(%)
Compressed work schedule 4/40		Yes/No	(%)
Compressed work schedule 9/80		Yes/No	(%)
Other Transportation Demand Measures			
	Secure Bike Parking	Yes/No	
	Showers/changing facilities provided	Yes/No	
	Guaranteed ride home program	Yes/No	
	Car-sharing services	Yes/No	
	Information on transportation alternatives	Yes/No	
	Dedicated employee transportation coordinator	Yes/No	
	Carpool matching program	Yes/No	
	Preferential carpool/vanpool parking	Yes/No	
Parking Supply (nonresidential)			
Actual Parking Spaces Provided		Note: separate input for each indicated land use type	
Step 2: Land Use Data			
		Quantity	**Units**
Residential			
	Single family housing		DU
	Apartments low rise		DU
	Apartments mid rise		DU
	Apartments high rise		DU
	Condo/townhouse general		DU
	Condo/townhouse high rise		DU
	Mobile home park		DU
	Retirement community		DU
	Congregate care (assisted living) facility		DU
Educational			
	Day-care center		ksf
	Elementary school		ksf
	Junior high school		ksf
	High school		ksf
	Junior college (2 years)		ksf
	University/college (4 years)		students
	Library		ksf

Place of worship		ksf
Recreational		
City park		acres
Racquet club		ksf
Racquetball/health		ksf
Quality restaurant		ksf
High turnover (sit-down) restaurant		ksf
Fast food rest. w/ drive thru		ksf
Fast food rest. w/o drive thru		ksf
Hotel		rooms
Motel		rooms
Large Retail		
Free-standing discount store		ksf
Free-standing discount superstore		ksf
Discount club		ksf
Regional shopping center		ksf
Electronic superstore		ksf
Home improvement superstore		ksf
Retail		
Strip mall		ksf
Hardware/paint store		ksf
Supermarket		ksf
Convenience market (24 hour)		ksf
Convenience market w/ gas pumps		ksf
Gasoline/service station		pumps
Commercial		
Bank (with drive-through)		ksf
General office building		ksf
Office park		ksf
Government office building		ksf
Government (civic center)		ksf
Pharmacy/drugstore with drive-through		ksf
Pharmacy/drugstore without drive-through		ksf
Medical office building		ksf
Hospital		ksf
Industrial		
Warehouse		ksf
General light industry		ksf
General heavy industry		ksf
Industrial park		ksf
Manufacturing		ksf
Blank		
Blank (Edit this description)		ksf/acres/other

Outputs

	Estimated Daily Vehicle Trips	Notes:
URBEMIS (Operational Unmitigated)	e.g. 24,322	Uses ITE trip generation rates *without* any operational mitigations
URBEMIS (Operational Mitigated)	**e.g. 19,423**	URBEMIS **estimate *with* selected operational mitigations**
Note: URBEMIS does not provide peak AM and PM trip estimates. Some consultants obtain these from ITE trip data and apply them to URBEMIS outputs.		

Validity Analyses - URBEMIS 2007 9.2.4

Input Sources and Assumptions

This section details the assumptions, data sources, and analytical processes used to generate URBEMIS estimates of vehicle trips for the ten EPA/SANDAG sites and the 12 California infill sites. Of the methods used in this study, URBEMIS 2007 9.2.4 is the most data intensive. The limited data available for the sites and URBEMIS's data requirements for selected vehicle operational mitigation measures made it necessary to collect data from a number of different sources. (note: "Mitigation Measures" in URBEMIS refer to both physical characteristics of a site and its vicinity, such as its density and transit availability, as well as demand measurement measures such as parking charges. See the last page for a detailed explanation of URBEMIS mitigation measures and their assumed efficacy.)

10 EPA/SANDAG Multi-Use Sites

While Gateway Oaks is the only site analysis described in detail here, the same assumptions, data sources, and analytical processes were used for the remaining sites: Jamboree Center, Park Place, The Villages, Rio Vista Station Village, La Mesa Village Plaza, Uptown Center, The Village at Morena Linda Vista, Hazard Center, and Heritage Center at Otay Ranch.

Following are the data sources and assumptions used for various URBEMIS vehicle "operational mitigations:"

Number of housing units within a ½-mile radius of site: The Census Bureau's LED OnTheMap (a tool available online at http://lehdmap4.did.census.gov) was used to generate a ½-mile radius around each site, selecting "Block Groups" for the Add Layer Selection. The percentage of each block group within a ½-mile radius of each site was estimated visually. Google Earth Pro was used to find the number of households in each block group (Nielsen Claritas, 2009). Lastly, the percentage of each block group within 1/2 mile of the site was multiplied with the number of households in that block group.

The sum of households within 1/2 mile of the site for all block groups was assumed to approximate the total number of housing units within a ½-mile radius of the site. This map shows the map of census block groups and a ½-mile radius around the Gateway Oaks site.

Assumption: On average, households are distributed evenly within the geographic boundaries of each census block group.

Employment within a ½-mile radius: LED OnTheMap was used to estimate the number of jobs within a ½-mile radius of each site using the following settings: for **Data Settings**, "Workplace area" was selected under Live or Work, "2008" for year, "All Jobs" for Job Type, and "All workers" for Labor Market Segments. For **Study Area Selection**, Google placemarks were imported for site location, "Block Groups" was selected for Add Layer Selection, and a radius of 1/2 mile was added for Add Buffer to Selection. "Work Area Profile Analysis" was selected for **Map Overlay/Report**. From these parameters, LED OnTheMap generated a report with an estimate of the **total number of jobs within a ½-mile radius** of the center of the site.

Transit services (# of daily buses, trains, shuttles): The "transportation" layer on Google Earth was used to locate transit stations within a ¼- and ½-mile radii of the site (these radii were generated using LED OnTheMap and imported into Google Earth). Google Earth also lists the routes for each stop and provides links to the local transit provider websites. These transit

provider sites post daily route schedules for each station. The number of unique buses stopping within 1/4 mile of the site was estimated using these schedules (avoiding double-counting buses that stopped multiple times within 1/4 of the site). This process was repeated for trains and shuttles where applicable (within a ½-mile radius of sites).

Percent of arterials/collectors with bike lanes (or where suitable, direct parallel routes exist): As with sidewalks, these were visually estimated using Google Maps. Where available, local bicycling maps were used to verify bicycle routes. Arterials were considered to be all streets colored yellow on Google Maps (as suggested by Ann Cheng of TransForm). Percentages were roughly estimated according to distances of road segments with and without bike lanes/direct parallel routes.

12 California Infill Study Sites

Number of housing units within a ½-mile radius: Residential density (DU/acre) provided for each site in the Infill Study report was multiplied by the # of acres within a ½-mile radius (approx. 503).

Employment within ½-mile radius: Employment density (# of workers/acre) provided for each site in the Infill Study report was multiplied by the # of acres within a ½-mile radius of each site.

Transit services: The same manual approach was used as for the 10 EPA/SANDAG sites (please see description above).

Percent of arterials/collectors with bike lanes (or where suitable, direct parallel routes exist): This input was visually estimated as for the EPA/SANDAG multi-use sites.

# of intersections per square mile: LED OnTheMap was used to draw a polygon around each site, and intersections were manually counted and divided by the area (in sq miles) of the polygon.

<u>Assumption:</u> The number of intersections per square mile within the site is approximately equal to the intersections per square mile in the area surrounding it (as the infill sites are too small to have intersections within their boundaries).

Peak Hours and URBEMIS output: Following a method used by the consulting firm Nelson-Nygaard, peak trips were derived from the URBEMIS daily vehicle trip estimates using ITE Trip Generation 8th edition peak-hour percentages for each land use category. (note: URBEMIS does not directly generate peak hour trips, and daily trip generation is calculated using ITE Trip Generation 7th edition rates.)

The following example shows the inputs used to generate the URBEMIS analysis for Gateway Oaks in Sacramento.

Site **Name**	**Gateway Oaks**		**Source/Notes**
	Geographic		
latitude		38.61	Mark Feldman, Google Earth placemarks[3]
longitude		-121.52	Mark Feldman, Google Earth placemarks
Address		2332 Gateway Oaks Dr, Sacramento, CA	Google Maps
AQMD		Sacramento	
Area (in acres)		227	EPA[4]
ITE Codes	**Land Use Classifications**		
	# of Dwelling Units		
220	Multi-Family	1,351	Low-Rise Apartments (Visual)[5], EPA
	Retail Floor Space (ksf)		
932	High Turnover Restaurant	12	EPA
	Office Floor Space (ksf)		
710	Non-Medical	1,084	EPA
310	**Hotel Rooms**	188	EPA
Operational Emission Sources			
Pass-by Trips		No	
Double-Counting Correction		No	
Operational Mitigations Selected and Data Inputs Used			
Mix of Uses			
# of housing units within 1/2 mile radius of site. Note: This includes the number of units in the site		1,613	Nielsen Claritas (2009), Google Earth Pro
Employment within 1/2 mile radius of site		4,108	U.S. Census Bureau LED OnTheMap
Local Serving Retail			
Presence of local serving retail - includes grocery store, pharmacy, hardware store, dry cleaners, corner store, café, stationary store, gym, etc.		Yes	

[3] Source: Mark Feldman of Fehr & Peers Consultants, who produced them for the 12 EPA/SANDAG multi-use study sites in California.
[4] The source "EPA" refers to CA Hilighted MXDSitesTripGenerationModelValidationEPAFinalSubmittedtoITE.xls.
[5] A visual inspection was done using Google Maps images to determine whether the apartments were Low-, Mid-, or High-rise.

Transit Services		
# of daily weekday buses stopping w/in 1/4 mile of site	57	http://www.sacrt.com/
# of daily rail or rapid transit buses stopping w/in 1/2 mile of site	0	
# of dedicated daily shuttle trips	0	
Bike and Pedestrians		
# of intersections per square mile within the site	85	EPA
Percent of streets within 1/2 mile of site with sidewalks on one side	100%	Google Maps[6]
Percent of streets within 1/2 mile of site with sidewalks on both sides	100%	Google Maps
Percent of arterials/collectors with bike lanes (or where suitable, direct parallel routes exist)	80%	No bike routes (visually on Google Maps) - El Camino and I-5
Outputs	**Estimated Daily Trips**	
URBEMIS (Operational *Unmitigated*)[7]	24,322	URBEMIS 2007 9.2.4 without mitigations
URBEMIS (Operational Mitigated)	**19,897**	URBEMIS 2007 9.2.4 using above inputs

Descriptions of Selected Operational Mitigation Measures

The following excerpts from the URBEMIS User's Manual describe each selected operational mitigation measure. (Note: additional text beyond the Manual is italicized.)

Mix of Uses

Trip reduction = (1- (ABS (1.5 * h e) / (1.5 * h + e)) 0.25) / 0.25 * 0.03
h = study area households (or housing units), e = study area employment.

This formula assumes an "ideal" housing balance of 1.5 jobs per household and a baseline diversity of 0.25. The maximum possible reduction using this formula is 9%. Negative reductions of up to 3% can result when the housing to jobs ratio falls to levels less than the baseline diversity of 0.25. This reduction takes into account overall jobs-population balance.

Local Serving Retail

The presence of local serving retail can be expected to bring further trip reduction benefits, and an additional reduction of 2% is assumed. This is towards the lower end of the values presented in the research, in order to avoid double counting with the diversity indicator.

Transit Services

[6] In most cases, 100% of streets within 1/2 mile of sites had sidewalks on both sides (excluding freeways)-these were estimated visually using Google Maps.
[7] "Operational Unmitigated" is the combined daily trip generation for all land uses in site from ITE Trip Generation, 7th edition.

The Transit Service Index emphasizes frequency but with greater weighting given to rail services. Greater weight is also given to dedicated shuttles, in recognition of the fact that these are likely to be more closely targeted to the needs of the development. The Transit Service Index is determined as follows:

Number of average daily weekday buses stopping within 1/4 mile of the site; plus
Twice the number of daily rail or bus rapid transit trips stopping within 1/2 mile of the site; plus
Twice the number of dedicated daily shuttle trips;
Divided by 900, the point at which the maximum benefits are assumed. (This equates to a BART station on a single line, plus four bus lines at 15-minute headways.)

As well as existing service, planned and funded transit service should be included in the calculation. Purely demand responsive service *(such as public "Dial-A-Ride")* should not be included. A maximum trip reduction of 15% is assumed. To account for non-motorized access to transit, half the reduction is dependent on the pedestrian/bicycle friendliness score. This ensures that places with good pedestrian and bicycle access to transit are rewarded.

Trip reduction = t * 0.075+ t * ped/bike score * 0.075
Where: t = transit service index

Bike and Pedestrian

The pedestrian/bicycle factor is calculated as follows:

Ped/bike factor = (network density + sidewalk completeness + bike lane completeness) / 3
Where: Network density = intersections [sum of valences] per square mile / 1300 (or 1.0, whichever is less)
Sidewalk completeness = % streets with sidewalks on both sides + 0.5 * % streets with sidewalk on one side
Bike lane completeness = % arterials and collectors with bicycle lanes, or where suitable, direct parallel routes exist

A maximum reduction of 9% is assumed. The trip reduction is calculated as:

Trip reduction = 9% * ped/bike factor

Parking Supply and Daily Parking Charge

In some cases where the number of site-specific parking spaces supplied was readily available, the Parking Supply and Daily Parking Charge mitigation measures were applied. URBEMIS assumes a maximum trip reduction of 25% for projects that commit to introducing parking pricing. The maximum reduction applies to prices of $6 per day or greater (in 2004 dollars). The trip reduction will therefore be as follows:

Trip reduction = daily parking charge / 6 * 0.25

The parking supply mitigation measure uses the Institute of Transportation Engineers Parking Generation, 3rd Edition handbook as the baseline. It applies only to non-residential land uses. The trip reduction is calculated as follows:

Trip reduction = 1- (Actual parking provision / (ITE Parking Generation rate * # units)

MTC Travel Survey-Based Vehicle Trip Adjustment Method

What it is:

A manual method that adjusts ITE vehicle trip rates using a regional travel survey conducted in 2000 by the Metropolitan Transportation Commission (MTC) in the San Francisco Bay Area.

Where it is used and who uses it:

The method is experimental. The data it is based on is from the San Francisco Bay Area; therefore its most appropriate application is in that region. It potentially can also be applied elsewhere in California that assuming density and transit proximity affect travel behavior in a similar manner. Alternatively, regional travel surveys specific to that region could be used to estimate vehicle trip rates.

To date, the method has only been used by the study team. However, others, including members of the Practitioners Panel, have voiced interest in developing a travel survey-based method.

Inputs:

This method requires project information sufficient to apply ITE trip rates, as well as information on surrounding area land use density and proximity to transit.

Outputs:

Key outputs from this method include daily and AM/PM peak hour trips by direction, as well as the estimated reduction from ITE rates.

How it works

This method adjusts ITE rates using project-vicinity characteristics. ITE vehicle trip generation rates are assumed to be representative of low-density suburban areas, given that this is where most ITE vehicle trip generation studies are performed. The method adjusts rates downward for other development contexts, based on vehicle trip rates found in these contexts as defined by density and transit proximity, based on data from the MTC regional travel survey.

Knowledge base:

This method currently utilizes travel survey data from the Bay Area Station Area Residents Study, conducted by MTC. It could potentially utilize data from other regions; however, to date, no other California planning agencies have analyzed household travel surveys in this manner.

References:

MTC website for StaRS: http://www.mtc.ca.gov/planning/smart_growth/stars/

Support Documents:

Various reports at the above website.

Please see the following page for more detailed information on inputs and outputs:

MTC Travel Survey-based Vehicle Trip Adjustment Method

The MTC Station Area Residents' Study (StaRS, 2006) set geographic areas (or buffers) around each rail and ferry stop in the Bay Area (in the case of MUNI, buffers were around the light rail stops). The buffers around rail/ferry stops defined three distance categories: within ½ mile, ½ mile to 1 mile, and greater than 1 mile. The study placed households into one of the three distance categories based on the location of the household with respect to the nearest rail/ferry stop. For households beyond one mile from a rail/ferry station, the study disaggregated them by population density using Census 2000 block group data. The four population density categories, along with examples of cities and communities for each group, were as follows:

1) Urban 10,000 or more persons/square mile e.g., San Francisco, Berkeley, Oakland.
2) High-Suburban 6,000 to 9,999 persons/ square mile, e.g., Palo Alto, Vallejo, Richmond, San Leandro.
3) Low-Suburban 500 to 5,999 persons/ square mile, e.g., Lafayette, Walnut Creek, Sausalito.
4) Rural Less than 500 persons/square mile e.g., Oakland Hills, Point Reyes Station, Guerneville.

Travel behavior within these categories was then extensively analyzed. Table 1 summarizes how vehicle driver trips per household vary among categories, normalized to the low-suburban category. The low-suburban density is used as the baseline, since this corresponds to the environment in which ITE trip generation rates data are typically collected.

TABLE 1: Vehicle Trip Factors Based on MTC StaRS Data

	Proximity of Household to Rail Station or Ferry Terminal					
	Within 1/2 mile	1/2 mile to 1 mile	Greater than 1 mile and Density /sq. mile			
Travel Characteristic:			Urban	High-Suburban	**Low-Suburban**	Rural
Vehicle Driver Trip Factor (percent driving compared to Low-suburban baseline)	**58.8%**	**75.4%**	**76.1%**	**91.9%**	**100.0%**	**94.4%**

The tool applies "vehicle trip factors" to ITE trip rates using the project vicinity density and station vicinity characteristics per Table 1 above (based on data presented in Table 4 in the MTC StaRS report). The method explicitly covers two important "D" factors – Density and Distance to Transit. While factors can also be developed for other travel modes, the vehicle trip factor is all that is currently used because ITE publishes only vehicle generation data.

A Hypothetical Example of the Method:

Project: A 150-unit Condominium development in a high-suburban density area (6,000-10,000 du/acre)

Vehicle Trip Reduction:

Multi-family housing (Unadjusted) ITE vehicle trips (LU 230):	801 daily vehicle trips
Apply vehicle trip factor for high-density suburban:	91.9% x 900 = 736 vehicle trips
Result after application of factor:	-65 vehicle trips

Validity Analyses – MTC Survey-Based Method

Input Sources and Assumptions

This section details the assumptions, data sources, and analytical processes used to generate estimates of vehicle trips for the sample sites. The survey-based method used in this study has modest data requirements. It requires classification of the project site into one of three distance-to-transit categories based on whether the site is: 1) within 1/2 mile, 2) between 1/2 and 1 mile, or 3) beyond 1 mile of a rail or ferry station.

For households beyond one mile from a rail or ferry station, the method requires further classification of project sites by population density, based on Census block groups. There are four population density categories (with examples from the San Francisco Bay Area) :[8]

1) Urban: 10,000 or more persons/square mile (e.g., San Francisco, Berkeley, Oakland).
2) High-Suburban: 6,000 to 9,999 persons/ square mile (e.g., Palo Alto, Vallejo, Richmond, San Leandro).
3) Low-Suburban: 500 to 5,999 persons/ square mile (e.g., Lafayette, Walnut Creek, Sausalito.)
4) Rural: Less than 500 persons/square mile (e.g., Oakland Hills, Point Reyes Station, Guerneville.)

Transit proximity: Google Maps were used to determine whether the site is located within 1/2 mile or 1 mile of a rail/ferry station.

Density: Calculated in persons/sq mile, this was determined by multiplying residential density (dwelling units (DU)/acre) for the project's Census block group by the number of acres in a

[8] MTC Station Area Residents Study (Volume 1) pp. 6-7; available at: http://www.mtc.ca.gov/planning/smart_growth/stars/

square mile (640), and then multiplying this quantity (DU/sq mi) by the average number of persons per DU obtained from Census data for the city.

Once this data is compiled, this data is used to produce a vehicle trip factor that can be used to adjust the ITE trip data for the project using the project vicinity density and station vicinity characteristics.

For this application, the initial focus was on five California Infill Sites in the San Francisco Bay Area because the survey method is based Bay Area survey data, so the method is most appropriate for these sites. The methodology was then extended to the other cordon count sites located in other regions.

The illustration below shows the transit station proximity and density classification for the California infill sites, along with the resulting trip adjustment factor applied to ITE trip rates for each project analyzed. For example, the four Los Angeles area projects are in the urban density category, and ITE trip rates are factored by 76.1% (highlighted in blue).

			MTC Survey-based Method		
			Transit-Density	Vehicle Trip	
Site #**	Site Name	Address	Classification	Adjustment	
1	Chain Clothing Store	1333 Broadway, Oakland, CA	<1/2 mile TrSta	58.80%	
2	1388 Sutter Street	1388 Sutter Street, San Francisco, CA 94109	<1/2 mile TrSta	58.80%	
3	Central City Association of Los Angeles	626 Wilshire Boulevard, Los Angeles, CA 90017	<1/2 mile TrSta	58.80%	
4	Horizon	505 Front Street, San Diego, CA 92101	<1/2 mile TrSta	58.80%	
5	Atria*	101 Market Street, San Diego, CA 92101	<1/2 mile TrSta	58.80%	
-	-	-	<1/2 mile TrSta	58.80%	
6	10351 Santa Monica Boulevard	10351 Santa Monica Boulevard, Los Angeles, CA	Urban	76.10%	
7	Wilshire Pacific Plaza	12301 Wilshire Boulevard, Los Angeles, CA	Urban	76.10%	
8	Archstone Santa Monica on Main	2000 Main Street, Santa Monica, California	Urban	76.10%	
9	Archstone Pasadena	25 South Oak Knoll Avenue, Pasadena, CA	Urban	76.10%	
10	Archstone Fox Plaza	1390 Market St., San Francisco, CA 94102	<1/2 mile TrSta	58.80%	
11	Pazzia Caffe and Trattoria	337 3rd Street, San Francisco, California	<1/2 mile TrSta	58.80%	
12	Bong Su	311 3rd Street, San Francisco, California	<1/2 mile TrSta	58.80%	
	*Atria has data reported for both a residential and commercial component (above).				
	**Site numbers have been assigned with regard to the order in which sites are reported.				

Evaluation of the Operation and Accuracy of Five Available Smart Growth Trip Generation Methodologies

Richard Lee
Josh Miller
Rachel Maiss
Mary Campbell
Kevan Shafizadeh
Deb Niemeier
and Susan Handy
Institute of Transportation Studies
University of California, Davis

with Terry Parker
California Department of Transportation

APPENDIX B:
Descriptions and comparisons of traffic counts sites

September 12, 2011

Appendix B: Descriptions and comparisons of traffic counts sites

Table of Contents

Introduction

The Smart Growth Trip Generation Project Team (Team) compared available traffic counts from ten sites from the EPA/SANDAG MXD study located in California against estimates from the candidate methodologies in order to determine which methodologies may be the most accurate. In addition to the EPA/SANDAG MXD sites, twelve smart growth sites, from which data were gathered for another project (Caltrans' Trip-Generation Rates for Urban Infill Land Uses in California) were used to test the candidate methodologies. Most of the EPA/SANDAG MXD sites are large-scale developments in more suburban areas, whereas the Infill sites are small-scale developments (in most cases, single buildings) located in urban cores. In this report, all of these sites are compared in light of their smart growth characteristics to better understand each site's potential to reduce vehicle trip generation rates. Smart growth characteristics are determined by examining the variables used to assess each site's trip generation rates, in addition to discussing some of the more qualitative characteristics of each site. Further, the "walkability" of each site is examined using "walkscore.com," which uses an algorithm to award points based on amenity provisions; however, only the number of commercial and public services within walking distance of a site are quantified. The walk score provides no indication of whether or not it is possible to walk to each amenity, so this portion of the analysis must be interpreted cautiously. Tables comparing the smart growth characteristics of each site are provided at the end of this document.

Review of Smart Growth Characteristics

Ten principles comprise the term "smart growth," all of which serve to foster a strong sense of place and community, encourage social equity, or reduce the environmental and social impacts of transportation. In particular, four of these principles tend to have a stronger effect on transportation than the rest. These four principles are as follows:

- *Take advantage of compact building design*: This is a synonym for development density, which countless studies over many decades have shown to be positively correlated with transportation modes other than the auto.
- *Mixed land uses*: This smart growth principle is important to take into account when estimating trip generation, because an appropriate diversity of land uses within one site tends to foster internal trips and, depending on site design, reduces overall vehicle trips.
- *Creation of walkable neighborhoods*: This principle is relevant to trip generation because walkable neighborhoods tend to encourage non-motorized travel, thus reducing overall vehicle trips. Density and land use mix play a fundamental role in the creation of walkable environments (by shortening trips and providing nearby destinations), but the presence of sidewalks, footpaths and bikeways providing direct routes between related land uses is also an essential component of walkability.
- *Provision of a variety of transportation choices*: This principle pertains to trip generation in the sense that providing various transportation choices and alternatives to the automobile can encourage reduction in overall vehicle trips. Walkability represents an essential first step toward providing transportation choices, and provision of walkways is a smart growth element that development projects should be expected to provide regardless of their scale.

Assessment of Smart Growth Characteristics of Study Sites in California

Data for the first ten sites were obtained for the EPA/SANDAG MXD study, whereas the data for the latter twelve sites were obtained for Caltrans' infill study. The first ten sites are primarily large, suburban mixed use developments, whereas the latter twelve are primarily small, single-use sites in urban cores. Refer to the tables following these descriptions for side-by-side comparisons of each site.

EPA/SANDAG MXD Study Sites

Gateway Oaks

Gateway Oaks is a 227-acre multi-use development in Sacramento, consisting of 1,351 multi-family dwelling units, 12,000 square feet of restaurant space, 1,084,000 square feet of office space, and 188 hotel rooms. Its residential density is 6 dwelling units per acre. The development contains 30 intersections, 8 bus stops, and no rail stops. The site has a mix of housing and office space, creating the potential for work trips to remain in the development. The site's walk score is 60 out of 100, indicating that it is "somewhat walkable," or contains some amenities within walking distance. The intersection density is low, which may affect walkability, but the higher transit station density may make transit a viable travel option within Gateway Oaks. The development is located about 3.5 miles from downtown Sacramento. The office space within the development was constructed from 1989 to 1998. (http://www.hines.com/property/detail.aspx?id=2101)

Jamboree Center

Jamboree Center is a 128-acre multi-use development in Irvine, consisting of 513 multi-family dwelling units, 111,000 square feet of retail space, 3,400 square feet of restaurant space, 12,000 square feet of gas stations, 10,000 square feet of auto repair space, 1,850,000 square feet of office space, 55,000 square feet of industrial space, and 522 hotel rooms. Its residential density is 4 dwelling units per acre. The development contains 22 intersections, 2 bus stops, and no rail stops. This development embodies the smart growth principles of compact building design and mixed land uses. However, 16% of the retail space is devoted to automobile maintenance and some of the land use mix is industrial. Thus, the site may not be especially pedestrian-friendly. The limited number of transit stops also reduces the availability of transit. The development's walk score is 54 out of 100, indicating that, like Gateway Oaks, it is somewhat walkable, with few amenities and services within walking distance. Jamboree Center is located about 3.5 miles from downtown Irvine, and 40 miles from downtown Los Angeles. The hotel and much of the office space were developed between 1985 and 1991, but some of the development at this site has continued into the past decade. (http://www.allbusiness.com/north-america/united-states-california-metro-areas/4091866-1.html)

Park Place

Park Place is a 109-acre multi-use site in Irvine, consisting of 162 high rise condominium units, 60,000 square feet of retail space, 30,000 square feet of restaurant space, and 1,643,000 square feet of office space. Its residential density is 1.5 dwelling units per acre. The site contains 12 intersections, 2 bus stops, and no rail stops. The site has a mix of land uses, and the high rise condos add to the level of development density. Once again, the low intersection and transit stop densities reduce the level of smart growth compatibility. The site's walk score is 75 out of 100, indicating that there is a fairly large number of services within the area. The development is located about 4 miles from downtown Irvine, and about 40 miles from downtown Los Angeles. The condominium units were completed in 2006, with some of the other development features still underway. (http://www.bosadev.com/residential/project_history.asp)

The Villages

The Villages is a 32-acre multi-use development in Irvine, consisting of 1,132 multi-family dwelling units, 2,070 square feet of retail space, and 2,400 square feet of restaurant space. Its residential density is 35.4 dwelling units per acre. The site contains 7 intersections, 2 bus stops, and no rail stops. The Villages has a mix of housing and commercial land uses, and the intersection and transit stop densities are higher than at most of the other sites examined. Thus, this site demonstrates significant smart growth characteristics. The site's walk score is 68 out of 100, suggesting that there are some services within the area. The development is about 4 miles from downtown Irvine, and 42 miles from downtown Los Angeles. The site was completed as a single development project in 2007. (http://www.mve-architects.com/portfolio/pr/165_The-Village-at-Irvine-Spectrum-Center)

Rio Vista Station Village

Rio Vista Station Village is a 16-acre multi-use development in San Diego, served by light rail and bus, and consisting of 970 multi-family dwelling units, 13,000 square feet of retail space, and 4,000 square feet of restaurant space. Its residential density is 59.3 dwelling units per acre. The site contains 4 intersections and 3 bus stops. This site exhibits a mix of residential and commercial land uses, with high residential density. Its walk score is 68 out of 100, indicating that there is a fair number of services available within walking distance in the area. The development is located about 5.5 miles from downtown San Diego, and was built in 2002. (http://www.promenadeliving.com/homeset.html)

La Mesa Village Plaza

La Mesa Village Plaza is a 6-acre multi-use development in La Mesa, also served by light rail and bus, which consists of 94 multi-family dwelling units, 14,300 square feet of office space, 22,200 square feet of restaurant space, and 8,000 square feet of retail space. Its residential density is 16.4 dwelling units per acre. This site contains 6 intersections and 1 bus stop. In addition to its mix of residential and commercial uses, this site incorporates about half as much office space as it has commercial space, increasing its mix of land uses and thus its smart growth compatibility. This site's walk score is 94 out of 100, indicating that there is a very large number of services available within walking distance in the area. The development is about 11 miles from downtown San Diego, and was completed in 1991. (http://www.uctc.net/papers/343.pdf)

Uptown Center

Uptown Center is a 14-acre multi-use development in San Diego, served by a high frequency local bus, consisting of 311 multi-family dwelling units, 137,200 square feet of retail (including a supermarket), and 3,000 square feet of government office space. Its residential density is 22 dwelling units per acre. The site contains 4 intersections and 2 bus stops. The supermarket on site may serve the needs of the residential community. However, the transit options do not compare to some of the other sites examined in the San Diego region, the light rail does not serve this area. Nonetheless, Uptown Center's walk score, like La Mesa Village Plaza, is 94 out of 100, indicating that there is a very large number of services available within walking distance in the area. The site is about 3 miles from downtown San Diego. It was built on the site of an old department store sometime between 1988 and 1991 (http://www.terrain.org/unsprawl/1/) and has become "...a model for redeveloping low-density, obsolete commercial sites for new housing and community uses" (http://www.gast-hillmer.com/uptown.html).

The Village at Morena Linda Vista

The Village at Morena Linda Vista is a 7-acre multi-use site in San Diego, served by light rail and bus, consisting of 185 multi-family dwelling units, 17,000 square feet of restaurant space, 8,000 square feet of retail space, and a transit station with 165 parking spaces. Its residential density is 28.1 dwelling units per acre. The site contains 6 intersections and 2 bus stops. This site has a good mix of residential and retail. Further, the light rail transit station located within the site provides better access to transit than others without rail transit. This site's walk score is 80 out of 100, indicating that there is a very large number of services available within walking distance in the area. The development is 5.5 miles from downtown San Diego, and was built in 2007. (http://www.villageatmorenavista.com/1)

Hazard Center

Hazard Center is a 16-acre multi-use development in San Diego, served by light rail, consisting of 98,700 square feet of retail space, 20,000 square feet of restaurant space, 284,000 square feet of office space, 300 hotel rooms, and 1,540 theater seats. The site contains no residential space. This site contains 5 intersections and 2 bus stops. It provides good commercial and recreational uses for employees on site and the light rail allows for larger scale access for employees and visitors alike. Further, the site's walk score is 86 out of 100, indicating that there is a very large number of services available within walking distance in the area. This development is located 4.7 miles from downtown San Diego, and was built in 1990. (http://hazardcenter.com/about/)

Heritage Center at Otay Ranch

Heritage Center at Otay Ranch is a 16-acre multi-use site in Chula Vista served by a high frequency local bus, with planned bus rapid transit service. Its residential density is 16.8 dwelling units per acre. The site consists of 271 multi-family dwelling units, 8,000 square feet of gas station space, with a food mart, 67,400 square feet of medical office space, and 38,000 square feet of retail space. It contains 3 intersections. This site provides a limited interaction of uses in comparison with many of the other sites. The retail space is likely of some use to residents, and some of the residents may work at the medical office space. However, transit facilities may be somewhat lacking due to the lack of light rail service. This site's walk score is 40 out of 100, indicating that there are a very few services and amenities available within walking distance in the area. The site is located about 14 miles from downtown San Diego, and was developed in 1999. (http://www.otayranch.com/about/aboutIndex.shtml)

California Infill Study sites

Chain Clothing Store

The chain clothing store is an 11,000 square foot retail development located in Oakland's central business district. The residential density within 0.5 miles of the development is 13.17 dwelling units per acre. The site's walk score is 100 out of 100, indicating that there is a very large number of services available within walking distance in the area.

1388 Sutter Street

Thirteen eighty-eight Sutter Street is an office building located in San Francisco's central business district, with 120,000 square feet of ground floor commercial space. The residential density within 0.5 miles of the building is 49.93 dwelling units per acre. This site has a high level of density, and its walk score is 98 out of 100, indicating that many services are available within walking distance of the area.

Central City Association of Los Angeles

The Central City Association of Los Angeles is an office building located in Los Angeles' central business district, with 138,542 square feet of ground floor commercial. The residential density within 0.5 miles of the site is 9.55 dwelling units per acre. The site's walk score is 98 out of 100, indicating that there is a large number of services within walking distance.

Horizon

Horizon is a high-rise residential complex with 211 dwelling units, located in San Diego's central business district. The residential density within 0.5 miles of the site is 8.86 dwelling units per acre. The site's walk score is 92 out of 100, indicating that many services are available within walking distance.

Atria

Atria is a residential complex with 149 dwelling units, located in San Diego's central business district, with 1250 square feet of ground floor commercial space. The residential density within 0.5 miles of the development is 8.64 dwelling units per acre. The site's walk score is 95 out of 100, indicating that there is a large number of services within walking distance.

10351 Santa Monica Boulevard

This is an office building located in Los Angeles' central business district, with 101,495 square feet of ground floor commercial space. The residential density within 0.5 miles of the development is 8.08 dwelling units per acre. The site's walk score is 92 out of 100, indicating that many services are within walking distance.

Wilshire Pacific Plaza

Wilshire Pacific Plaza is an office building located in Los Angeles' central business district, with 105,977 square feet of ground floor commercial space. The residential density within 0.5 miles of the development is 14.60 dwelling units per acre. The site's walk score is 80 out of 100, indicating that there is a large number of services within walking distance.

Archstone Santa Monica

Archstone Santa Monica is a residential complex with 133 dwelling units located 1 mile from Santa Monica's central business district and 16 miles from Los Angeles' central business district. The residential density within 0.5 miles of the development is 10.24 dwelling units per acre. The site's walk score is 80 out of 100, indicating that many services are within walking distance.

Archstone Pasadena

Archstone Pasadena is a residential complex with 120 dwelling units and 1800 square feet of ground floor commercial, located in Pasadena's central business district. The residential density within 0.5 miles of the development is 10.13 dwelling units per acre. The site's walk score is 92 out of 100, indicating that there is a very large number of services within walking distance.

Archstone Fox Plaza

Archstone Fox Plaza is a high-rise residential complex with 443 dwelling units located in San Francisco's central business district. The residential density within 0.5 miles of the building is 24.35 dwelling units per acre. The site has a high level of density, and its walk score is 97 out of 100, indicating that many services are within walking distance.

Pazzia Caffe and Trattoria

Pazzia Caffe and Trattoria is a 3,000 square foot restaurant located in San Francisco's central business district. The residential density within 0.5 miles of the restaurant is 9.85 dwelling units per acre. The site's walk score is 95 out of 100 indicating that there is a very large number of services within walking distance.

Bong Su

Bong Su is a 6,000 square foot restaurant located in San Francisco's central business district. The residential density within 0.5 miles of the development is 9.9 dwelling units per acre. The site's walk score is 95 out of 100 indicating that there is a very large number of services within walking distance.

Conclusions

Based on walk score, mix of land uses, density, and transit provision, each of the sites demonstrates smart growth characteristics to some extent. Four of the EPA/SANDAG MXD sites are served by light rail, and the rest are served by some kind of bus transit, most achieved reasonable walk scores, and all demonstrate a significant mix of land uses. When compared with the infill sites, the EPA/SANDAG MXD sites tended to achieve lower walk scores, but the residential densities of these developments were higher than those of the infill sites, on average. The fact that none of the EPA/SANDAG MXD sites are located in the central business district may contribute to the lower walk scores, whereas the infill sites tended to get higher walk scores due to their urban locations. Overall, despite the fact that only a few of the EPA/SANDAG MXD sites demonstrate significant smart growth characteristics, most are improvements over isolated, low-density, suburban areas such as those used to derive the ITE trip generation rates. Further, the infill sites were in very dense urban areas, with many diverse land uses, making them exemplary smart growth developments.

Table 1: Smart Growth Principle: *Take Advantage of Compact Building Design*			
EPA/SANDAG MXD Sites:	**Intersections/ Acre**	**Dwelling Units/Acre**	**Distance to CBD (Miles)**
Gateway Oaks, Sacramento	0.13	6.0	3.5
Jamboree Center, Irvine	0.17	4.0	3.5 (Irvine), 40 (L.A.)
Park Place, Irvine	0.11	1.5	4 (Irvine), 40 (L.A.)
The Villages, Irvine	0.22	35.4	4 (Irvine), 42 (L.A.)
Rio Vista Station Village, San Diego	0.24	59.3	5.5
La Mesa Village Plaza, La Mesa	1.05	16.4	11
Uptown Center, San Diego	0.28	22.0	3
The Village at Morena Linda Vista, San Diego	0.91	28.1	5.5
Hazard Center, San Diego	0.32	0.0	4.7
Heritage Center at Otay Ranch, Chula Vista	0.19	16.8	14
EPA/SANDAG MXD site average	0.36	19	5.9
Infill Study Sites:	**Intersections/ Acre**	**Dwelling Units/Acre (Within 0.5 miles)**	**Distance to CBD (Miles)**
Chain Clothing Store, Oakland	N/A	13.2	Within
1388 Sutter Street, San Francisco	N/A	50	Within
Central City Association of L.A.	N/A	9.6	Within
Horizon, San Diego	N/A	8.9	Within
Atria, San Diego	N/A	8.6	Within
10351 Santa Monica Blvd, L.A.	N/A	8.1	Within
Wilshire Pacific Plaza, L.A.	N/A	14.6	Within
Archstone Santa Monica on Main, Santa Monica	N/A	10.2	1 (Santa Monica), 16 (L.A.)
Archstone Pasadena, Pasadena	N/A	10.1	Within
Archstone Fox Plaza, San Francisco	N/A	24.4	Within
Pazzia Cafe and Trattoria, San Francisco	N/A	9.9	Within
Bong Su, San Francisco	N/A	9.9	Within
Infill Study Site Average	N/A	14.8	0.1

Table 2: Smart Growth Principle: *Mixed Land Uses*								
	Residential Space (Dwelling Units)	**Commercial Space (Square Feet)**	**Office Space (Square Feet)**	**Industrial Space (Square Feet)**	**Commercial Space (%)**	**Office Space (%)**	**Industrial Space (%)**	**Hotel Rooms**
Gateway Oaks, Sacramento	1,351	12000	1084000	0	1%	99%	0%	188
Jamboree Center, Irvine	513	114400	1850000	55000	6%	92%	3%	522
Park Place, Irvine	162	90000	1643000	0	5%	95%	0%	0
The Villages, Irvine	1132	4470	0	0	100%	0%	0%	0
Rio Vista Station Village, San Diego	970	17000	0	0	100%	0%	0%	0
La Mesa Village Plaza, La Mesa	94	30200	14300	0	68%	32%	0%	0
Uptown Center, San Diego	311	137200	3000	0	98%	2%	0%	0
The Village at Morena Linda Vista, San Diego	185	25000	0	0	100%	0%	0%	0
Hazard Center, San Diego	0	118700	284000	0	30%	70%	0%	300
Heritage Center at Otay Ranch, Chula Vista	271	46000	67400	0	41%	59%	0%	0

Table 3: Smart Growth Principle: *Creation of Walkable Neighborhoods*	
EPA/SANDAG MXD Sites:	**Walk Score (Out of 100)**
Gateway Oaks, Sacramento	60
Jamboree Center, Irvine	54
Park Place, Irvine	75
The Villages, Irvine	68
Rio Vista Station Village, San Diego	68
La Mesa Village Plaza, La Mesa	94
Uptown Center, San Diego	94
The Village at Morena Linda Vista, San Diego	80
Hazard Center, San Diego	86
Heritage Center at Otay Ranch, Chula Vista	40
EPA/SANDAG MXD Study Site Average	72
Infill Study Sites:	**Walk Score (Out of 100)**
Chain Clothing Store, Oakland	100
1388 Sutter Street, San Francisco	98
Central City Association of L.A.	98
Horizon, San Diego	92
Atria, San Diego	95
10351 Santa Monica Blvd, L.A.	92
Wilshire Pacific Plaza, L.A.	80
Archstone Santa Monica on Main, Santa Monica	80
Archstone Pasadena, Pasadena	92
Archstone Fox Plaza, San Francisco	97
Pazzia Cafe and Trattoria, San Francisco	95
Bong Su, San Francisco	95
Infill Study Site Average	93

Table 4: Smart Growth Principle: *Provision of a Variety of Transportation Choices*		
	Bus	**Light Rail**
Gateway Oaks, Sacramento	√ *(8 Stops)*	
Jamboree Center, Irvine	√ *(2 Stops)*	
Park Place, Irvine	√ *(2 Stops)*	
The Villages, Irvine	√ *(2 Stops)*	
Rio Vista Station Village, San Diego		√
La Mesa Village Plaza, La Mesa		√
Uptown Center, San Diego	√	
The Village at Morena Linda Vista, San Diego		√ *(1 Station)*
Hazard Center, San Diego		√
Heritage Center at Otay Ranch, Chula Vista	√	

Maps of Site Locations ***(unless noted otherwise, all images taken from Google Maps)***

Gateway Oaks, Sacramento:

Jamboree Center, Irvine:

Park Place, Irvine:

The Villages, Irvine:

Rio Vista Station Village, San Diego:

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STATION VILLAGE AT RIO VISTA STATION

Image taken from SANDAG's *Trip Generation for Smart Growth*

La Mesa Village Plaza, La Mesa:

Image taken from SANDAG's *Trip Generation for Smart Growth*

Uptown Center, San Diego:

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UPTOWN CENTER

Image taken from SANDAG's *Trip Generation for Smart Growth*

Morenda Linda Vista Station, San Diego:

Image taken from SANDAG's Trip Generation for Smart Growth

Hazard Center, San Diego:

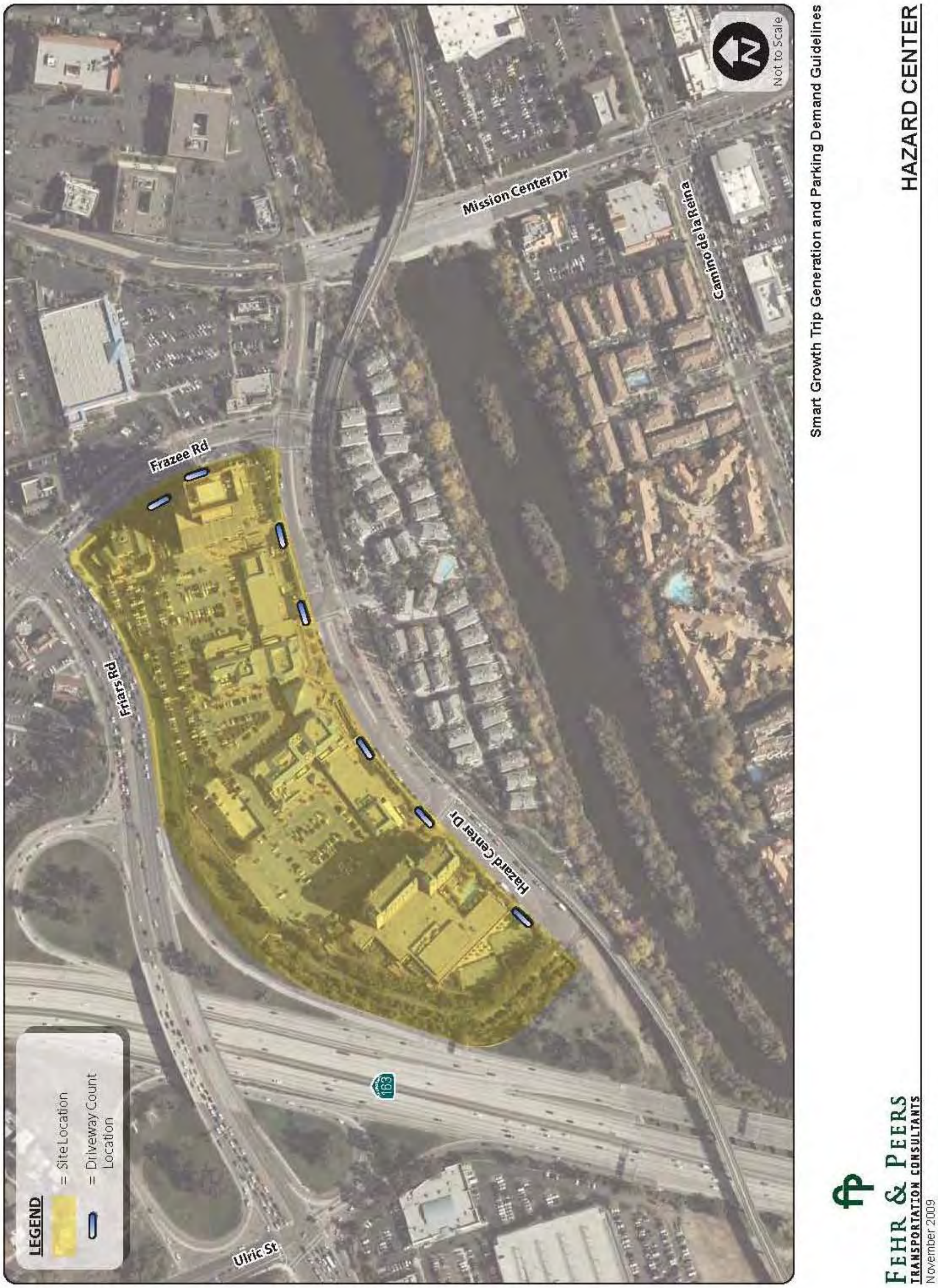
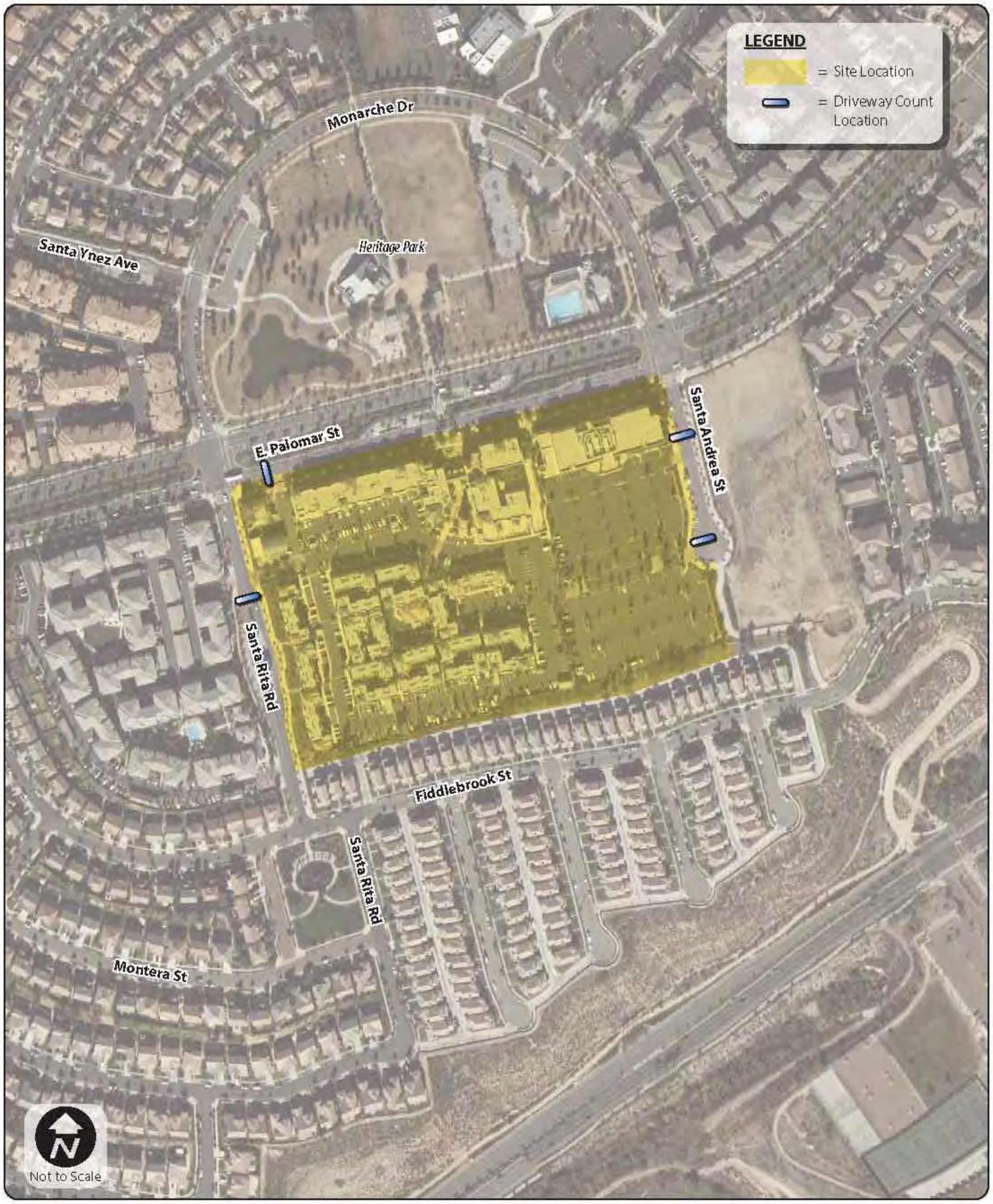


Image taken from SANDAG's *Trip Generation for Smart Growth*

Heritage Center at Otay Ranch, Chula Vista:



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OTAY RANCH

Image taken from SANDAG's *Trip Generation for Smart Growth*

Infill study's San Francisco Bay Area sites:

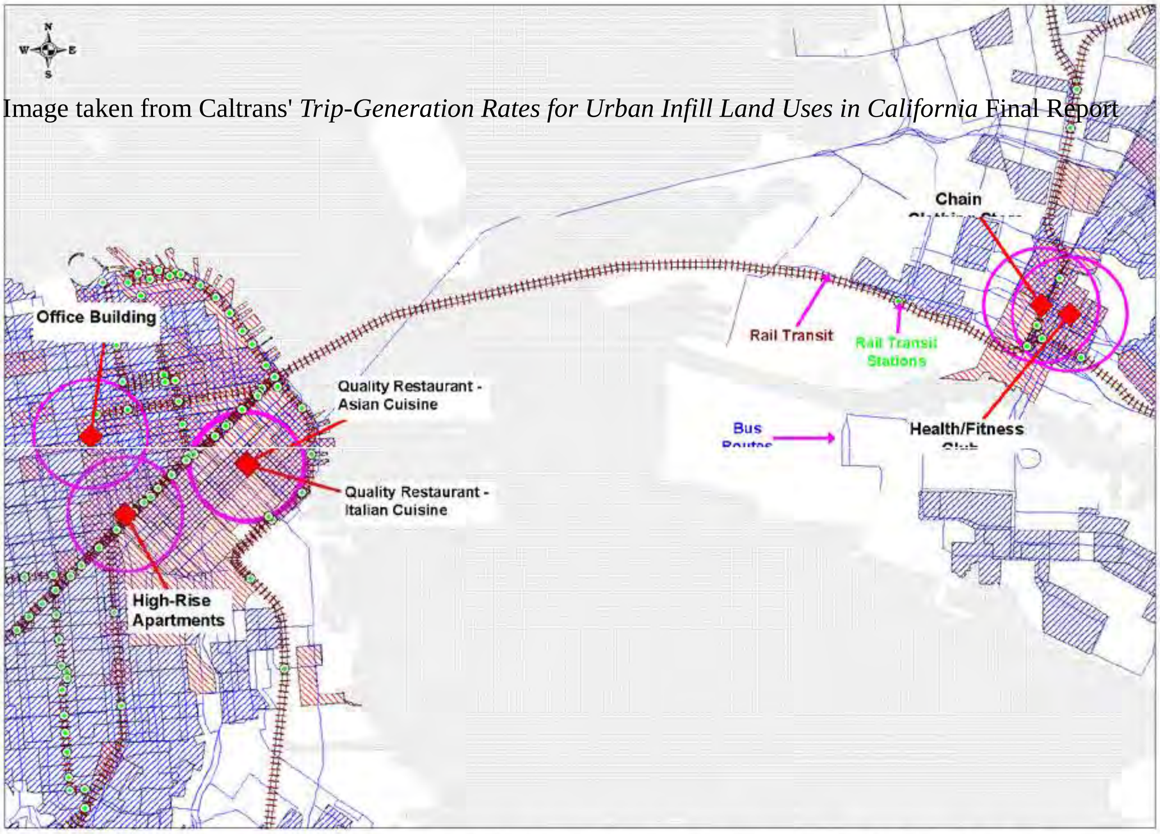


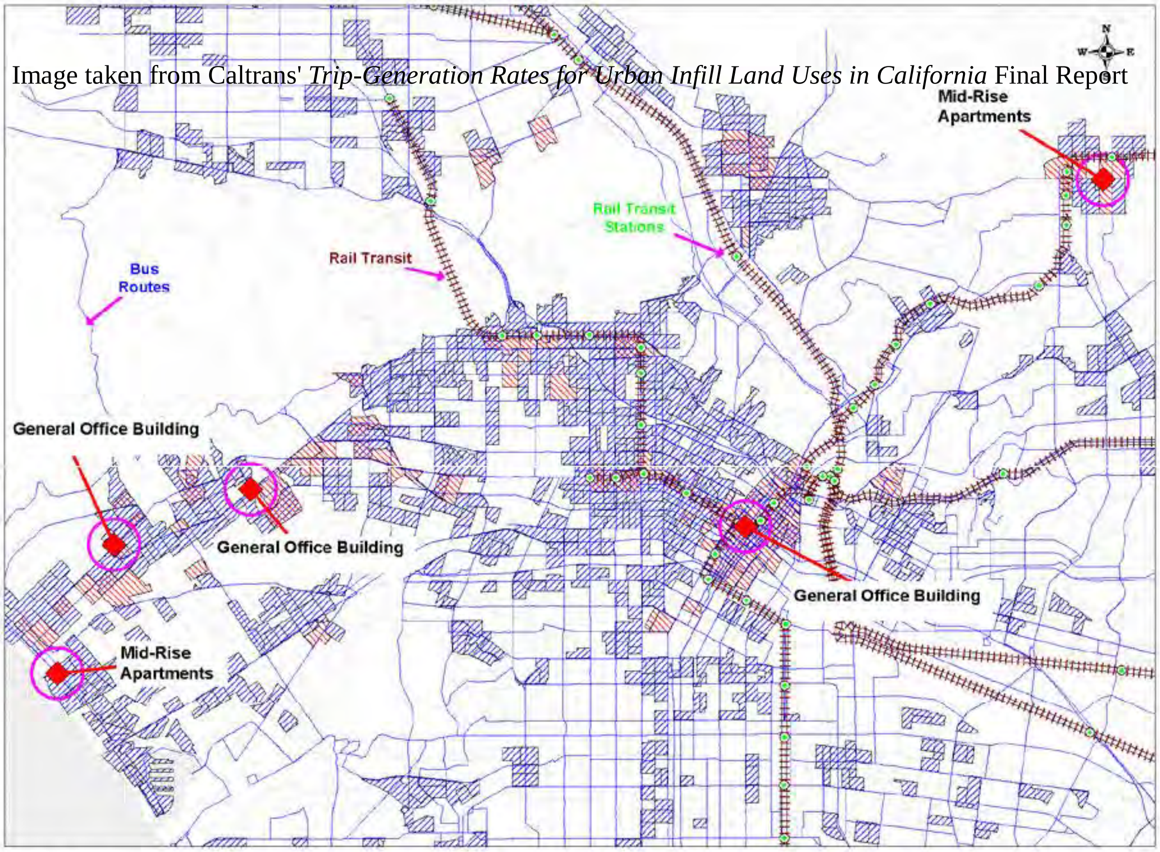
Image taken from Caltrans' *Trip-Generation Rates for Urban Infill Land Uses in California* Final Report

* Block Groups Shown with Red hachure had Year 2000 workers >= 35 per gross land acre; with Blue hachure had Year 2000 DU >= 10 per gross land acre.

Economic & Planning Systems, Inc. One-half mile radii shown around surveyed sites. *P:\17000s\17104Caltrans\Maps\MapInfo\Figure 1.wor*

Infill study's Los Angeles Area sites:

Image taken from Caltrans' *Trip-Generation Rates for Urban Infill Land Uses in California* Final Report

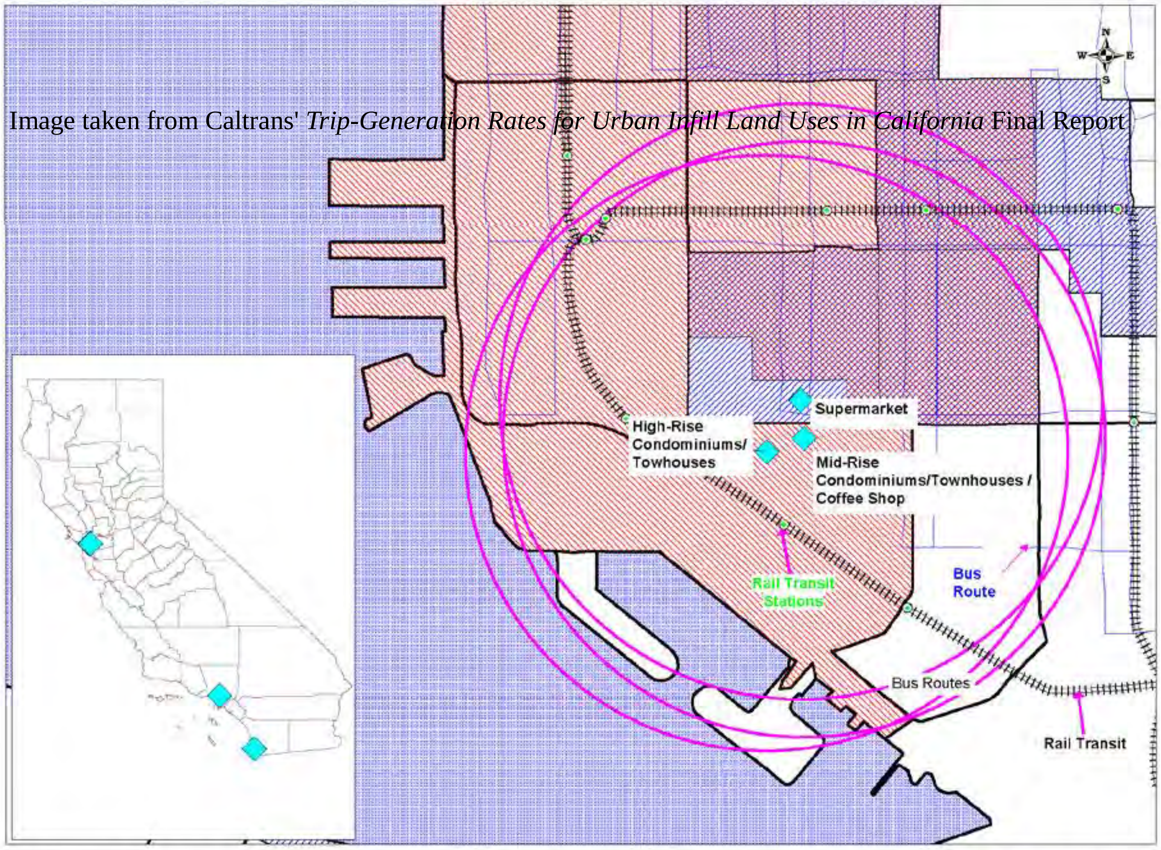


* Block Groups Shown with Red hachure had Year 2000 workers >= 35 per gross land acre; with Blue hachure had Year 2000 DU >= 10 per gross land acre.

Economic & Planning Systems, Inc. One-half mile radii shown around surveyed sites. *P:\17000s\17104CaltransMaps\MapInfo\Figure 2.wor*

Infill study's San Diego Area sites:

Image taken from Caltrans' *Trip-Generation Rates for Urban Infill Land Uses in California* Final Report



* Block Groups Shown with Red hachure had Year 2000 workers >= 35 per gross land acre; with Blue hachure had Year 2000 DU >= 10 per gross land acre.

Economic & Planning Systems, Inc. One-half mile radii shown around surveyed sites. *P:\14000s\14002abag_infill\Maps\Mapinfo\Fig_Final_E5.wor*

Site Addresses

Gateway Oaks
2150 River Plaza Drive
Sacramento, CA 95833

Jamboree Center
1 Park Plaza
Irvine, CA 92614

Park Place
Michelson Drive
Irvine, CA 92612

The Villages
8105 Irvine Center Dr
Irvine, CA 92618

Rio Vista Station Village
2185 Station Village Way
San Diego, California 92108

La Mesa Village Plaza
7914 La Mesa Blvd
La Mesa, CA 91942

Uptown Center
1270 Cleveland Avenue
San Diego, California 92103

The Village at Morena Linda Vista
5395 Napa Street
San Diego, CA 92110

Hazard Center
7676 Hazard Center Drive
San Diego, CA 92108

Heritage Center at Otay Ranch
1580 La Media Road
Chula Vista, CA 91913

Chain Clothing Store
1333 Broadway
Oakland, CA 94612

1388 Sutter Street
San Francisco, CA 94109

Central City Association of Los Angeles
626 Wilshire Boulevard
Los Angeles, CA 90017

Horizon
505 Front Street
San Diego, CA 92101

Atria
101 Market Street
San Diego, CA 92101

10351 Santa Monica Boulevard
Los Angeles, CA 90025

Wilshire Pacific Plaza
12301 Wilshire Boulevard
Los Angeles, CA 90025

Archstone Santa Monica on Main
2000 Main Street
Santa Monica, California 90405

Archstone Pasadena
25 South Oak Knoll Avenue
Pasadena, CA 91101

Archstone Fox Plaza
1390 Market St.
San Francisco, CA 94102

Pazzia Caffe and Trattoria
337 3rd Street
San Francisco, California 94107

Bong Su
311 3rd Street
San Francisco, California 94107

Evaluation of the Operation and Accuracy of Five Available Smart Growth Trip Generation Methodologies

Richard Lee
Josh Miller
Rachel Maiss
Mary Campbell
Kevan Shafizadeh
Deb Niemeier
and Susan Handy
Institute of Transportation Studies
University of California, Davis

with Terry Parker
California Department of Transportation

APPENDIX C:
Practitioners Panel Survey on Operational Criteria

September 12, 2011

Appendix C: Practitioners Panel Survey on Operational Criteria

As part of the UC Davis-Caltrans project, "Trip-Generation Rates for Smart-Growth Land Use Projects in California," the project team created an on-line survey to allow Practitioner Panel members to rank operational criteria that had been identified through shared discussions. Eleven panel members opened the on-line survey. Eight completed the survey. Respondents were allowed to skip questions, so there is not a consistent number of respondents for each question. Typically, there were eight responses to each question. Respondents were asked to rate criteria from 1 to 6 with 1 being the "least important" and 6 being the "most important" ranking for each criterion. The average response from 1 to 6 is shown in the shaded column. **Responses are listed in the order of highest to lowest averages for each category. Top-rated criteria are listed on the last page** (page 8).

1. **The following operational criteria relate to a methodology's <u>Ease of Use.</u> Please review the list below and rate the importance of the criteria. 1=least important and 6=most important. You can rate more than one criterion with the same importance/rating.**

Criteria	**Least Important………..…....** **1**	**2**	**3**	**4**	**5**	**...Most Important** **6**	**N/A ***	**Rating Average**	**Response Count**
User-friendliness		1	1		3	3		4.8	8
Difficulty of obtaining required data			2	2		4		4.8	8
Transparency	1	1	1		3	2		4.1	8
Data needs			3	2	2	1		4.1	8
Time to analyze a Project		2	2	3	1			3.4	8
Use voluntary	1	3	3				1	2.3	8

**N/A column is only shown in tables where was a response listed in that column.*

Comments from respondents:

1. Logic and ease of explaining to analysis reviewers so they will accept method and its results.
2. I think data needs, difficulty of obtaining data, and effort to use available data are all part of user-friendliness. If it takes too much time to obtain, process, and evaluate data, the method is no long user friendly.
3. Hard questions to answer because the answers may be different for different locations/situations.
4. If a methodology doesn't give the right answer then its other virtues are for “naught.”

2. **Please rate the following <u>Method Sensitivities Criteria</u> in order of importance. 1=least important and 6=most important. You can rate more than one criterion with the same importance/rating.**

Criteria	Least Important……………………...Most Important						Rating Average	Response Count
	1	**2**	**3**	**4**	**5**	**6**		
LU context variables		1			3	4	5.1	8
Project-level Variables		1		1	2	4	5.0	8
Transport Variables		1		2	1	4	4.9	8
Transit headways/Change in service		1	1	3	1	2	4.3	8
Urban design variables		2		3	2	1	4.0	8
Parking supply/pricing		1	2	3	1	1	3.9	8
Pedestrian/Bicycle Connectivity		1	2	2	2		3.7	7
Use of 7Ds		3	1	3		1	3.4	8
Starts with person trips, then allocates to modes	4		1	1		1	2.4	7
Gas Prices	3	3	1	1			2.0	8

3. **Please rate the following <u>Input Data Mechanics</u> criteria in order of importance. 1=least important and 6=most important. You can rate more than one criterion with the same importance/rating.**

Criteria	**Least Important……………….**					**Most Important**	**N/A**	**Rating Average**	**Response Count**
	1	**2**	**3**	**4**	**5**	**6**			
Sensitivity of output to inputs						7		6.0	7
Uses local information		1			7			4.6	8
Difficulty of obtaining required data			2	2		3		4.6	7
Amount of data needed about the project's context &/or area nearby.			2	1	2	2	1	4.6	8
Can it work without regional or local travel models?	1			2	3	2		4.5	8
2-tiered data inputs for data-poor/-rich areas		1	2	1		4		4.5	8
Borrowed data OK		1	1	2	3	1		4.3	8
Amount of data needed about the proposed project.			2	1	2	1	1	4.3	7
Relates Smart Growth indicators to inputs	1	1	1		1	3		4.1	7
Effort to use available data			1	2	4	1		3.6	8

Comment from respondent:
Did not understand [items about amount of data]. (*note – these were clarified for subsequent survey respondents*)

4. **Please rate the following <u>Output</u> <u>Criteria</u> in order of importance. 1=least important and 6=most important. You can rate more than one criterion with the same importance/rating.**

Criteria	**Least Important……………Most Important**						**N/A**	**Rating Average**	**Response Count**
	1	**2**	**3**	**4**	**5**	**6**			
Results replicable by other analysts					2	6		5.8	8
AM / PM / daily / other time frames reported				1	3	4		5.4	8
Auto vs. “other” trip generation rates				1	3	3		5.3	7
“Internal capture” shown?			1	1	3	3		5.0	8
Project description by land use(s) and size?			1	3		4		4.9	8
Inputs?			1	3	1	2	1	4.6	8
Analyst can adjust model	1		1	1	2	3		4.5	8
Include and distinguish between future traffic volumes and a project’s trip generation rate			4	1		2	1	4.0	8
Effect of transit service on travel	1		2	2	2	1		3.9	8
Graphical representation of raw vs. final trip gen. data	1	1	2	1		3		3.8	8
Link reduced trips to a reduction in VMT		3	1	2	2			3.4	8
Effect of bike and pedestrian facilities on travel		2	4		2			3.3	8

5. **Please rate the following Additional Criteria in order of importance. 1=least important and 6=most important. You can rate more than one criterion with the same importance/rating.**

Criteria	**Least Important……………..Important**					**Most**	**N/A**	**Rating Average**	**Response Count**
	1	2	3	4	5	6			
Results should not fluctuate excessively.					3	4	1	5.6	8
Can the method measure the performance of different kinds of land use projects?					3	4		5.6	7
Can the method be used to define a range for reductions in ITE rates?		1	1	2	1	2		4.3	7
Does the method identify a context for a development that qualifies it as smart growth?	1	3		1		3		3.6	8
Can the method define different categories of smart growth based on size, urban area, etc?	1	2	1	1	1	2		3.6	8
Complex equations should be converted to simpler graphs and/or tables.	1	2		2	2	1		3.6	8
Can the method group certain types of smart growth within parameters to comprehend complex development mixes?	1		4	1	2			3.4	8

Comment from respondent:
[item on fluctuation in results] - the results should not differ from one run to the next if inputs are the same.

TOP-RATED CRITERIA

Criteria	Least Important……………...Most Important						N/A	Rating Average	Response Count
	1	2	3	4	5	6			
Sensitivity of output to inputs						7		6.0	7
Results replicable by other analysts					2	6		5.8	8
Results should not fluctuate excessively.					3	4	1	5.6	8
Can the method measure the performance of different kinds of land use projects?					3	4		5.6	7
AM / PM / daily / Other time frames reported				1	3	4		5.4	8
Auto vs. "other" trip generation rates				1	3	3		5.3	7
LU context variables		1			3	4		5.1	8
"Internal capture" shown?			1	1	3	3		5.0	8
Project-level Variables		1		1	2	4		5.0	8
Transport Variables		1		2	1	4		4.9	8
Project description by land use(s) and size?			1	3		4		4.9	8

California Smart-Growth Trip Generation Rates Study

Final Report

Appendix E

Institute of Transportation Studies

University of California, Davis

Davis, CA 95616

DATA COLLECTION METHODOLOGY AND RESULTS

California Smart-Growth Trip Generation Rates Study

University of California, Davis for the California Department of Transportation
November 2012

AUTHORS
Robert Schneider, Ph.D., University of California, Davis
Kevan Shafizadeh, Ph.D., California State University, Sacramento
Benjamin Sperry, Ph.D., Texas Transportation Institute
Brian Bochner, PE, Texas Transportation Institute
Susan Handy, Ph.D., University of California, Davis

Table of Contents

1. INTRODUCTION

There is currently no commonly-accepted methodology in the U.S. to collect trip generation data and estimate trip-generation rates for land use projects in "smart-growth" areas. Standard trip generation estimation methods established by the Institute of Transportation Engineers (ITE) are derived from data obtained mostly at suburban locations that lack good transit or pedestrian facilities (ITE Trip Generation Handbook 2004). This makes it very difficult, if not impossible, for practitioners to accurately estimate the actual transportation impacts of developments proposed in places where it is convenient to use many different modes of travel. By following existing guidelines, transportation engineers often over-prescribe automobile infrastructure in smart-growth locations, resulting in wider roadways, more turning lanes, and more parking spaces than necessary. In addition, there is no established approach to recommend adequate pedestrian, bicycle, or public transit facilities that may improve conditions for traveling by these other modes.

The purpose of this report is to describe the data collection and analysis methodology used in this study to document the number of pedestrian, bicycle, public transit, and automobile trips generated by developments in smart-growth areas. This multimodal trip generation data collection and analysis approach was applied at 30 study locations in California. It is intended to be replicated and refined in other communities seeking to collect trip generation data in smart-growth areas. This approach builds upon established methods so that it can be integrated easily into standard transportation engineering and planning practice. Ultimately, the results of this and other smart-growth trip generation studies will benefit practitioners seeking to evaluate developments that support sustainable transportation and land use systems.

1.1. Definitions

There is no detailed, broadly-established definition of smart growth. However, in general, **smart-growth areas** are places where many common activities (e.g., workplaces, parks, coffee shops, stores, other homes) are located within a convenient walking distance of where many people live and work. Smart-growth areas are also typically served by pedestrian and bicycle facilities and frequent and reliable public transportation.

Data were collected at **targeted land uses** (also referred to as "study locations") within smart-growth areas. Targeted land uses represented a single ITE land use category. Some of these targeted land uses occupied an entire site (e.g., a shopping center development), while other targeted land uses were part of a **multi-use development** (e.g., one specific use within a development that had a combination of residential, office, retail, or other uses).

A **person-trip** is defined here as the movement of one person between two activity locations. Travel from a person's previous activity location to one of the study locations is an **inbound**

trip. Travel from one of the study locations to the person's next activity location is an **outbound trip**. The sum of inbound and outbound trips is the total number of trips generated at the study location. The **person-trip generation rate** is the total number of trips generated at the study location during a one-hour period per square foot (for office and retail land uses) or per dwelling unit (for residential land uses). This study further defines the **morning peak-hour person-trip generation rate** as the highest rate for a one-hour period between 7 a.m. and 10 a.m. and **afternoon peak-hour person-trip generation rate** as the highest rate for a one-hour period between 4 p.m. and 7 p.m. The **automobile-trip generation rate** is the total number of automobile trips generated at the targeted activity location during a one-hour period per square foot (for office and retail land uses) or per dwelling unit (for residential land uses). If two people are traveling in the same automobile to a targeted activity location, they are making two person-trips by automobile but only one automobile trip.

People often use more than one type, or mode, of transportation on trips between two activity locations. This may include walking a few blocks and then taking the bus for several miles or driving an automobile for several miles and then walking a few blocks. Bus stops, parking lots, or other places where people simply change modes are not defined as activity locations. This study defines the **primary trip mode** as the mode used by a person for the longest distance on his or her trip between two activity locations.

2. PREVIOUS SMART-GROWTH TRIP GENERATION RESEARCH

Researchers have evaluated the differences between published ITE trip generation rates and actual (observed) trip generation rates at sites with smart-growth characteristics over more than a decade (Tindale Oliver and Associates 1993; Steiner 1998; Muldoon and Bloomberg 2008; Arrington and Cervero 2008; Kimley Horn Associates 2009; Bochner *et al*. 2011). Table 1 summarizes findings from several of these comparative studies. Most of these studies have been based on observations at fewer than 20 sites. They focus on various land use types, from mixed-use developments to individual residential, retail, office, and other uses in urban infill areas.

2.1. Differences between ITE and Actual Trip Generation Rates

Early comparisons of ITE and actual trip generation rates found mixed results: some developments with smart-growth characteristics generated fewer automobile trips than ITE estimates, but other developments generated more trips than predicted (Tindale Oliver and Associates 1993; Steiner 1998; Muldoon and Bloomberg 2008). High automobile trip generation rates in smart-growth areas may have been due to abnormally high economic activity at some sites or specific site characteristics that did not support the use of walking, bicycling, or public transit (e.g., sites with large parking lots or bounded by high-speed multi-lane roadways). Actual automobile trips may also have exceeded predicted trips in some cases because of differences in trip rate estimation methods (Tindale Oliver and Associates 1993; Muldoon and Bloomberg 2008).

Recent studies with larger sample sizes and more consistent site characteristics have shown that ITE methods overestimate trips generated at smart-growth sites. For example, a sample of 17 residential transit oriented developments (TODs) averaged 44% fewer daily vehicle-trips than estimated by ITE (Arrington and Cervero 2008). Based on a multivariate regression analysis, this study also found that residential density within one-half mile of the transit station was the variable most correlated with trip generation rates. Another study found actual morning peak-hour trip rates to be between 27% and 50% lower than ITE rates and actual afternoon peak-hour trip rates to be between 26% and 50% lower than ITE rates for mid-rise apartments, general office buildings, and quality restaurants at urban infill sites (Kimley Horn and Associates 2009).

However, the number of studies comparing ITE predictions with actual trip data is still small, and combining data from these studies yields an overall sample that is limited for conducting statistical analyses. Therefore, more data is needed to quantify adjustments to ITE trip generation estimates for specific land uses in smart-growth areas.

2.2. Data Collection Methods at Sites with Smart-Growth Characteristics

Several different methods have been used to collect trip generation data at sites in smart-growth areas. One approach is to use pneumatic tubes to count automobiles entering and exiting driveways at study site boundaries (Tindale Oliver and Associates 1993; Muldoon and Bloomberg 2008; Arrington and Cervero 2008). However, this approach does not measure automobile trips to and from the site that use street parking or other off-site public parking facilities. Therefore, pneumatic tubes are not an accurate method for smart-growth developments that have limited on-site parking. In addition, because pneumatic tubes do not count pedestrian trips and may not capture all bicycle trips, this method is not suitable for multimodal trip generation studies. Several research teams have overcome this problem by using a combination of door counts and intercept surveys (Kimley Horn Associates 2009; Bochner et al. 2011). Most intercept surveys have used paper forms, but handheld electronic tablets have also been tested (Muhs et al. 2012). This survey-based approach has also been used in the United Kingdom (JMP Consultants 2012) and New Zealand (Pike 2011).

Table 1. Previous Studies of ITE-Predicted vs. Actual Trips at Smart-Growth Sites

Authors (Year)	Study Location(s)	Number of Study Sites	Type(s) of Sites	Data Collection Method	Study Time Period	Comparison Time Period(s)	General Findings
Tindale Oliver and Associates (1993)	Broward County and Palm Beach County, FL	3	Multi-use developments (residential, office, and retail)	Vehicle counts at site boundary entry points	June 29 to July 22, 1993	*Daily trips *AM peak-hour trips *PM peak-hour trips	*Observed daily trips were 10% to 16% lower than ITE trips estimated from the sum of individual retail uses *Observed daily trips were 23% to 30% higher than ITE trips estimated from the aggregated shopping center use
Steiner (1998)	East Bay of the San Francisco Bay Area, CA	6	Traditional shopping districts surrounded by moderate- to high-density residential areas	Intercept surveys	Not reported	*Average hourly trips on weekdays and Saturdays *Average daily trips on weekdays and Saturdays	*Observed average hourly trips were lower than ITE trips at 4 of 6 sites on weekdays and 2 of 6 sites on Saturdays *Observed daily trips were lower than ITE trips at 6 of 6 sites on weekdays and 5 of 6 sites on Saturdays
Muldoon and Bloomberg (2008)	Oregon	5	Single-use developments in urban areas (retail, office, or industrial)	Vehicle counts at site boundary entry points	Not reported	*Daily trips *Peak-hour trips	*Observed peak-hour trips were lower than trips predicted by traffic impact studies at 3 of 5 sites *Observed daily trips were higher than trips predicted by traffic impact studies at 3 of 3 sites
Arrington and Cervero (2008)	Philadelphia, PA/NJ; Portland, OR; Washington, DC/MD/VA; East Bay of the San Francisco Bay Area, CA	17	Residenial transit-oriented developments	Vehicle counts at site boundary entry points	May 29 to May 31, 2007	*Weekday trips *AM peak-hour trips *PM peak-hour trips	*Observed weekday trips were 44% lower than ITE trips *Observed AM peak trips were 49% lower than ITE trips *Observed PM peak trips were 48% lower than ITE trips
Kimley Horn and Associates (2009)	Los Angeles, CA; San Diego, CA; San Francisco, CA	25	Urban infill developments (mid- to high-density residential, office, retail, and quality restaurant uses)	Intercept surveys and person counts at doorways	Spring 2006, Spring 2007, Fall 2007, Spring 2008, Fall 2008	*AM peak-hour trips *PM peak-hour trips	*Observed AM peak trips were 27% lower and observed PM peak trips were 28% lower than ITE trips for 3 mid-rise apartments *Observed AM peak trips were 50% lower and observed PM peak trips were 50% lower than ITE trips for 4 general office buildings *Observed AM peak trips were 35% lower and observed PM peak trips were 26% lower than ITE trips for 2 quality restaurants
Bochner et al. (2011)	Dallas/Fort Worth, TX; Atlanta, GA; Florida	5	Mixed-use developments (office, retail, restaurant, cinema, hotel, and residential)	Vehicle (and occupancy) counts at site boundary entry points		*AM peak-hour inbound and outbound trips *PM peak-hour inbound and outbound trips	*Observed inbound AM trips were lower than ITE mixed-use method for 4 of 5 sites *Observed outbound AM trips were lower than ITE mixed-use method for 3 of 5 sites *Observed inbound PM trips were lower than ITE mixed-use method for 4 of 5 sites *Observed outbound PM trips were lower than ITE mixed-use method for 5 of 5 sites

3. GENERAL DATA COLLECTION APPROACH

The data collection approach was structured to be straightforward, easily replicated, and adaptable to any potential land use and smart-growth development type. It builds on established ITE site-based trip generation data collection guidelines. This section provides an overview of the data collection timeframe and process used to derive multimodal trip counts at 30 study locations. Additional details are provided in subsequent sections.

3.1. Study Timeframe

The study timeframe was chosen so that the trip generation data collected at smart-growth study locations could be compared easily to standard trip generation data. Overall trip generation rates and modal trip generation splits at smart-growth study locations may vary by the time-of-day, day of the week, season of the year. However, the timeframe selected for this study matches the most common time periods evaluated in practice. Established trip generation practices typically focus on weekday morning and afternoon commute travel periods, which often have the highest amount of traffic across the transportation system as a whole. It is important to recognize that travel to and from some specific land use types (e.g., schools, churches, restaurants) may peak at different times or on different days than the transportation system as a whole. Transportation system impacts at times other than weekday commute periods (e.g., mid-day or weekend peaks) are an important topic for future research, but this study focused on overall peak periods rather than peaks specific to individual land uses.

This project collected data during the following periods:

- *Time of day*. Data were collected from 7 a.m. to 10 p.m. and 4 p.m. to 7 p.m. The final analysis focused on the weekday afternoon peak hour, defined as the one-hour period with the highest automobile trip generation rate within the 4 p.m. to 7 p.m. timeframe. While morning peak-hour data were collected at some study locations, the afternoon peak hour was analyzed rather than the morning because more afternoon survey responses were available at study locations.[1]
- *Day of the week*. Data were collected on typical weekdays, including Tuesday, Wednesday, and Thursday.

[1] Door counts were collected from 7 a.m. to 10 a.m. at all study locations (excluding commercial retail uses that did not open before 10 a.m.). Intercept surveys were collected from 7 a.m. to 10 a.m. at residential and coffee/donut shop study locations, and some trip information was gathered for the 7 a.m. to 10 a.m. period from 4 p.m. to 7 p.m. surveys at office study locations. Intercept surveys were not conducted from 7 a.m. to 10 a.m. at office study locations because they were offered only as people exited doorways, and relatively few people exited offices in the morning period. At some residential land uses, door counts were collected from 6:30 a.m. to 10 a.m. to see if the morning peak hour was earlier than 7 a.m. to 8 a.m. However, this was not the case at any of the study locations. This study used three-hour data collection periods instead of the two-hour data collection periods recommended by ITE (7 a.m. to 9 a.m. and 4 p.m. to 6 p.m.). Three-hour data collection periods were used rather than shorter periods to capture more intercept survey responses and create a better estimate of trip mode shares at targeted land uses. For some sites, the AM peak hour was later than 8 a.m. to 9 a.m. and PM peak hour was later than 5 p.m. to 6 p.m., meaning that the number of person-trips and vehicle-trips counted at these sites was slightly higher than would have been recorded by standard ITE methods.

- *Season of the year*. Data were collected during spring 2012. The pilot study was done March 29th, and the other study locations were completed between April 24th and May 24th (before Memorial Day).

Data were only collected on typical days when school was in session. The data collection time periods did not represent any seasonal peaks or lows at study locations.

3.2. Data Collection and Analysis Process

The data collection and analysis process included the following four main components, described in greater detail below:

1) Select study locations in smart-growth areas where trip generation data could be collected efficiently.
2) Collect data to quantify the total number of person-trips generated and percent of person-trips by mode for each study location.
3) Combine multimodal person-trip data with vehicle occupancy information to estimate actual automobile-trip generation rates.
4) Compare actual automobile-trip generation rates to ITE automobile-trip generation rates.

Step 1. Select Study Locations in Smart-growth Areas

Study locations were selected in a variety of areas throughout California that have smart-growth characteristics. In general, these locations were surrounded by urban development, had many activities located within walking distance, and had good access to public transportation. Detailed guidelines for selecting the smart-growth study locations are presented later in the report.

Overall, there were two different approaches to data collection at study locations. Some study locations were entire, multi-activity sites (i.e., trip generation was evaluated for an entire development of residential, retail, and office uses). Other study locations were targeted land uses within a larger development (e.g., trip generation was evaluated for individual uses). The types of land uses targeted for the study are described later in the document.

Step 2. Collect Data to Quantify Total Person-Trips Generated by Mode

Field data were collected in spring 2012 at 30 study locations. A combination of door counts and intercept surveys was used to quantify the total number of person-trips made to and from each study location by pedestrians, bicyclists, transit users, and automobile users during the afternoon peak hour. This information was combined with vehicle occupancy data to estimate an automobile trip generation rate in Step 3. The combination of door counts and surveys was preferred over standard automobile tube counts for several reasons:

- Automobile tube counts at driveways and other site access points do not provide an accurate count of automobile trips, especially at smart-growth study locations because 1) automobile users may park on the street or in an off-site parking lot and then walk to the study location and 2) people may park at a site but walk to a different location nearby without accessing a targeted land use (this is especially common at sites that have shared parking or general public parking).

- Automobile tube counts at driveways and other access points to a site do not capture trips made by other modes.

It was necessary to combine door counts and surveys to gather accurate multimodal trip generation data. This combination of data collection methods was preferred over using either method independently for several reasons:

- Simple door counts cannot determine whether each person's main mode of transportation is walking, bicycling, public transit, or automobile. Similarly, counting people at the boundary of a development will not identify whether a pedestrian is walking as their primary mode, walking to or from a parked car, or walking to or from transit (Pike 2011). Intercept surveys gathered detailed travel characteristics from respondents so that their primary trip modes could be determined accurately.
- It is impractical to survey all people exiting a building. Therefore, door counts were necessary to quantify the total number of person-trips generated by each targeted land use. These counts were used to extrapolate the intercept survey data to represent the total number of person-trips by mode of transportation at each targeted land use.

Step 3. Estimate Actual Automobile Trip Generation Rates

The multimodal person counts and intercept surveys were used to estimate automobile trip generation rates. Door counts provided the total number of person-trips to and from the study location during the afternoon peak hour. The intercept survey showed the proportion of all trips that were made by automobile as well as automobile occupancy. The total number of person-trips was multiplied by the proportion of trips by automobile to derive automobile person-trips. These automobile person-trips were then divided by the average automobile occupancy at each site to calculate the number of motor vehicle-trips generated at each study location during the afternoon peak hour.

Step 4. Compare Actual Automobile Trip Generation Rates with ITE Rates

The previous step provided an estimate of the actual afternoon peak-hour automobile-trip generation rates at each study location. ITE afternoon peak-hour automobile-trip generation rates were derived from study location characteristics (e.g., number of residential units, number of gross square feet of office space) using the ITE Trip Generation Manual (2008). The difference between the actual automobile-trip generation rates and ITE rates will be the focus of further analysis.

3.3. Comparison to Other Approaches

The research approach used in this study was based on ITE data collection guidelines for trip generation studies[2]. Basic ITE requirements were followed, though some aspects were modified to capture data efficiently and accurately at study locations with smart-growth characteristics. The only ITE site selection guideline that was not considered in the criteria for selecting study locations in this document is the recommendation to count at isolated sites and discourage counting at study locations where pedestrian and transit access are common. Since

[2] Institute of Transportation Engineers. *Trip Generation Handbook: An ITE Recommended Practice*, Second Edition, Principal Editor: Hooper, K.G., June 2004.

the purpose of this project is to gather data at smart-growth sites and collect data on different modes, the count and intercept survey methodology has been designed to capture these modes accurately[3].

Other methods have also been used to gather and analyze trip generation data at study locations in smart-growth areas. Several of these alternatives to the current ITE method were considered but not used for a variety of reasons:

- Technically, estimates of trips generated for large areas can be derived from household travel surveys. The recently completed 2009 National Household Travel Survey and the new California statewide and regional travel surveys scheduled in 2012 offer a way to design an approach similar to that of the Environmental Protection Agency (EPA) Mixed-Use Developments (MXD) method. However, the sparseness of data in these surveys necessitates pooling respondent information over relatively large geographic areas to achieve reasonable sample sizes. The sample of household travel survey trips is even smaller for peak-hour trips. These issues make the regional-scale travel diary approach considerably less suitable for infill and other smaller smart-growth projects. Additionally, travel diaries, which are household-based, miss important trips such as commercial trips by delivery trucks.
- Travel diary surveys may be used to estimate adjustments to vehicle-trip rates based on mode splits for travel zones, as done in the San Francisco Bay Area[4]. Dr. Kelly Clifton at Portland State University is using this approach with travel data from the Puget Sound Regional Council[5]. This approach accounts for characteristics of development in the zone but not characteristics of the project itself.
- Workplace surveys are available from some studies[6], but these data typically focus on commute and related employee trips, leaving customer visits, deliveries, and other business travel uncounted.
- More specialized household surveys have been conducted with higher sample sizes in selected areas in studies examining the relationship between land use patterns and

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[3] Site selection guidelines are on pp. 17-18 of the ITE *Trip Generation Handbook: An ITE Recommended Practice* (2004).

[4] San Francisco Bay Area Metropolitan Transportation Commission. "Characteristics of Rail and Ferry Station Area Residents in the San Francisco Bay Area." Available online: http://www.mtc.ca.gov/planning/smart_growth/stars/, 2006.

[5] Clifton, K.J., K.M. Currans, A.C. Cutter, and R.J. Schneider. "A Context-Based Approach for Adjusting Institute of Transportation Engineers Trip Generation Rates in Urban Contexts Using Household Travel Surveys," Presented at Transportation Research Board Annual Meeting, Washington, DC, 2012.

[6] For example:

- Chatman, D. "Transit-Oriented Development and Household Travel: A Study of California Cities." Institute of Transportation Studies, School of Public Affairs, UCLA. For the CA Dept. of Transportation (Caltrans). At: http://www.policy.rutgers.edu/faculty/chatman/documents/TODs_and_travel_in_CA.pdf, August 2006.
- Cervero, R. "Built Environments and Mode Choice: Toward a Normative Framework," *Transportation Research D*, Vol. 7, pp. 265-284, 2002.
- Cervero, R. and K. Kockelman. "Travel Demand and the 3Ds: Density, Diversity, and Design," *Transportation Research D*, Vol. 2, No. 3, pp. 199-219. 1997. (Compilation of several previous studies.)
- Cervero R.. "Traditional Neighborhoods and Commuting in the San Francisco Bay Area," *Transportation* 23: 373-394, 1996.
- Cervero, R.. "Suburban Employment Centers: Probing the Influence of Site Features on the Journey-to-Work," *Journal of Planning Education and Research* 8, 2: 75-85, 1989.

travel behavior. Unless these surveys included a travel diary, they do not provide a way to estimate trips generated. Household travel diary data could potentially be used to estimate trip generation for residential land uses but it would be impractical for commercial uses.

4. SMART-GROWTH SELECTION CRITERIA AND STUDY LOCATION CHARACTERISTICS

The analysis focused on trip generation data at study locations in smart-growth areas. Three principles guided the study location selection process.

1) Study locations should meet objectively-defined smart-growth criteria and include at least one specific land use targeted by this study.
2) Study locations should have similar characteristics to other locations where trip generation analyses are applied.
3) Study locations must be practical for conducting intercept surveys and cordon counts.

The detailed guidelines in the following sections helped identify study locations to achieve the overall goals of the project. Note that some study locations chosen for data collection in spring 2012 did not meet every single guideline. The guidelines were treated with enough flexibility to identify a sufficient sample of study locations for analysis. For future data collection efforts, these guidelines should not be viewed as rigid constraints that preclude a study location that meets nearly all of the criteria but does not quite meet the minimum or maximum threshold for a few characteristics.

4.1. Smart-Growth Characteristics

The smart-growth guidelines in this subsection provide more specific information related to the four smart-growth principles described in "Evaluation of the Operation and Accuracy of Five Available Smart Growth Trip Generation Methodologies"[7] and include characteristics commonly used as smart-growth measures by the State of California[8] and other organizations[9,10]. Since there are no detailed, broadly-established smart-growth standards, the smart-growth guidelines used for this project were established collaboratively by the project Research Team and Practitioners Panel. Study locations were selected to meet the following criteria:

- The area within 0.5 miles of the study location should be mostly developed[11]. The study location should not be on the periphery of an urban area.
- There should be a mix of land uses in the area within 0.25 miles of the study location. In general, single-use zoning is not consistent with smart-growth principles.
- There should be at least 6,000 residents living within 0.5 miles of the study location (7,639 residents/mi^2) or at least 1,000 jobs within 0.5 miles of the study location (1,273

[7] Lee, R., J. Miller, R. Maiss, M.M. Campbell, K.R. Shafizadeh, D.A. Niemeier, S.L. Handy, and T. Parker. *Evaluation of the Operation and Accuracy of Five Available Smart Growth Trip Generation Methodologies*. Appendix B, Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-11-12, 2011.

[8] California Senate Bill 375, 2008. Section 13 defines "infill site," and Section 14 defines "transit priority project."

[9] US Green Building Council. *A Citizen's Guide to LEED for Neighborhood Development: How to Tell if Development is Smart and Green*, Available at: http://www.nrdc.org/cities/smartgrowth/files/citizens_guide_LEED-ND.pdf 2011.

[10] Washington Smart Growth Alliance. *Smart and Sustainable Growth Recognition Criteria*, Available online: http://www.sgalliance.org/documents/SGRPCriteriaOnly.9-1-2010.pdf, 2010.

[11] Smart-growth criteria that use area measurements were calculated from simple, straight-line buffers at specified distances from the center of the study location. A 0.5-mile radius translates to 0.785 square miles.

jobs/mi^2)[12]. These values provide a rough measure to ensure that the study location is close to a sufficient number of people and activities. Note that the sites ultimately selected for field data collection met a minimum density threshold of at least 6,000 residents within 0.5 miles of the study location (7,639 residents/mi^2) or at least 12,000 jobs within 0.5 miles of the study location (15,280 jobs/mi^2), which exceeded the original goal.

- The study location should be served by frequent transit service. During a typical weekday PM peak hour, there should be at least: a) ten bus stop locations for all bus lines that pass within a 0.25-mile radius around the study site, or b) five individual train stop locations for all train lines that pass within a 0.5-mile radius around the study site[13]. Ferry terminals should not be considered.
- The study location should have bicycle lanes, multi-use pathways, or other designated bicycle facilities within two blocks[14].
- There should be more than 50% sidewalk coverage on streets within 0.25 miles of the study location (100% sidewalk coverage is sidewalks on both sides of all streets; 50% sidewalk coverage is a sidewalk on one side of all streets or sidewalks on both sides of half of streets).

4.2. Study Location Characteristics for Transferrable Results

Study locations were selected to be comparable with other similar developments throughout California and the United States. This made it easier to integrate the results of the project with existing trip generation analysis practices. The following guidelines were established to make the results more transferrable to other locations:

- The study location should contain at least one of the following land uses:
  - Mid-to-high density residential, including apartment (ITE land use code 220), high-rise apartment (222), mid-rise apartment (223), residential condominium/townhouse (230), or high-rise residential condominium/townhouse (232) (developments that contain more than 50% subsidized, low-income residential units should be excluded).
  - Office, including general office building (710).
  - Retail, including specialty retail (814), shopping center (820), or pharmacy/drugstore without drive-through window (880).

[12] 7,639 residents/mi^2 is equivalent to 4.6 dwelling units per gross acre, assuming the national average of 2.6 residents per household, and 1,273 jobs/mi^2 is equivalent to about 2 jobs per gross acre. Appendix A includes more detail on how the numbers of residents and jobs within a 0.5-mile radius were calculated.

[13] 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.

[14] 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.

    - Coffee/donut shop without drive-through window (936).[15]
- The land use mix within and surrounding the study location should be similar to other developments (i.e., it is not so unique that the trip generation data would not apply to other sites). For example, the following should be avoided:
    - Specific land uses with higher-than-normal overall customer bases, such as the only grocery store in an entire downtown district.
    - Study locations in university areas. This includes study locations within 1.0 miles of a university with 5,000 or more students and study locations within 0.5 miles of census tracts with more than 15% of the population between ages 18 and 21.
    - Study locations that include or are located within 0.5 miles of stadiums, military bases, commercial airports, major tourist attractions, "specialty" shopping areas (e.g., Union Square in San Francisco), subsidized housing projects, or other special attractors that are not typically included in trip generation studies.
- There should be no construction or other activity at or near a study location that restricts access and activity volume.
- The site or targeted land use should be at least 80% occupied and at least two years old. As a rule of thumb, retail and residential developers generally look to achieve 90% occupancy. Below 75% occupancy is considered a failed retail development. Office developers look for 85% occupancy.

4.3. Study Location Features for Efficient Data Collection

It was important for study locations to be practical for conducting door counts and intercept surveys. The following guidelines helped identify study locations for efficient data collection:

- Permission must be obtained from the property owner/manager to collect data at each site or targeted use[16]. Even if a study location has ideal smart-growth characteristics and land use types, it may not be possible to collect data because the property owner will not grant permission. In most cases, the property owner or manager communicates with internal businesses, residents, and other tenants about permission for the study. In some cases, the survey supervisor may need to make direct contact with individual owners to gain full permission. Therefore, study locations under ownership or management of one entity are preferred over locations with multiple owners or

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[15] The targeted land uses were limited to these specific land use codes in order to have a manageable number of land use codes to study. Since other types of land uses were not studied, they may have different trip generation characteristics in smart-growth areas.

[16] Obtaining permission to collect data at specific sites or targeted uses was essential to implementing the door count and intercept survey methodology. For future data collection efforts, the survey supervisor should contact property management by phone and e-mail, and then meet as necessary to discuss the purpose and procedures of the data collection effort. During each contact, the survey supervisor should emphasize that the data collection team 1) will be professional, 2) will not impede or hassle tenants or customers (any person who refuses to participate in the intercept survey will be left alone), and 3) will not divulge proprietary or sensitive information. An incentive for property management to cooperate may be to offer the opportunity to receive the survey results or a copy of the study report. In some cases, when permission is first requested, the initial contact person may not allow data collection. However, follow-up calls or visits with the initial contact or someone at a higher management level (e.g., corporate headquarters) may help ease concerns and secure permission. In other cases, the first contact person may initially provide permission, but their boss or corporate management may later rescind permission. Because it is challenging to obtain permission, it is important to have a list of potential backup study locations.

managers due to the complexity of obtaining permission to collect data.

- It must be possible to count all people entering and exiting all doorways of the targeted land use. If data collectors are prohibited from viewing a doorway that is used at least occasionally, the site should not be selected.
- Multi-use buildings should have definable internal boundaries (e.g., doors where counts can be taken) between different targeted land uses. For example, in a mixed-use office building with a restaurant on the ground floor, data should be collected at internal doors that connect the restaurant to the office space (as well as other external doors to both uses). If ground-floor retail or restaurant units have no internal connection to other uses within the building, they can be evaluated independently.
- To conserve data collection resources, the study location should have a limited number of doorways. In general, one door counter and one intercept surveyor is needed at each door. Yet, it is possible to increase the coverage of each data collector at certain types of study locations.
    - At some study locations, a single door counter can observe two or three different doors simultaneously from a carefully-selected vantage point. This works best at locations with relatively low levels of activity.
    - It may be possible for a single intercept surveyor to cover more than one doorway at the same time. This is possible when doors are no more than 20 to 30 feet apart.
    - It may be possible for a single intercept surveyor to rotate among several doors, spending specific time intervals at each door so that the probability of intercepting an individual from each door over the entire data collection period is roughly equal.
    - In undesirable cases where certain doors are counted but not surveyed, it is possible to extrapolate survey responses from a carefully-chosen sample of other similar doors at these sites. However, as the percentage of surveyed doors becomes smaller, extrapolation estimates become less accurate.
- The study location should not have significant through traffic. If there are people who pass through the building doors without accessing a targeted land use on the site (e.g., people who use public parking in a building before walking to another building or people who access a different use in the building that is not being studied), these trips should be identified through intercept surveys. These trips should be excluded from the analysis.
- A study location should have enough activity to provide a sufficient number of intercept survey interviews during a single day of data collection. The research team set a goal to record at least 50 trips (absolute minimum of 30 trips) during each afternoon peak period at each study location. Sample sizes of less than 30 are typically avoided to ensure the sample results benefit from the central limit theorem that says the sampling distribution of the means will approach that of a normal distribution even if the population being sampled is not normally distributed[17]. For planning purposes, the research team assumed that 20% of people exiting targeted land uses would be surveyed, and these people would report one trip (the trip they were taking from the targeted use to their next activity location). This suggested that there should be at least 250 people exiting during each three-hour data collection period (average of 83 exits

[17] *Fundamental Research Statistics for the Behavioral Sciences*, John T. Roscoe, Holt, Rinehart and Winston, Inc., 1969.

per hour).

4.4. Field Visits to Finalize Study Locations

Field visits were made to most study locations before the day of data collection. Field visits were conducted to:

- Select specific buildings and uses within buildings to be targeted for data collection.
- Observe activity patterns within and around the study location and anticipate how activity patterns may change between morning and evening peak periods (based on observed movements and land use types).
- Observe how people travel to and from transit stops, parking lots, and parking garages to access the study location.
- Note whether parking lots and garages allow public parking. This may suggest that people use an on-site parking lot but do not go to any of the targeted land uses on the site.
- Estimate the total number of data collectors needed to do door counts and intercept surveys at each study location (e.g., identify any locations where a single counter or surveyor could cover more than one door or any low-activity doors where surveyors may not be needed).
- Identify where data collectors should stand outside of all doors at each study location during morning and evening periods.
- Anticipate potential challenges to data collection.
- Record data on explanatory variables that can only be collected in person.

Google Street View was used to review site characteristics at several remote study locations before data were collected in the field. This worked, but it was not ideal. Image sources like this do not always have up-to-date pictures, do not always indicate whether parking garages allow public parking, do not show internal building doorways between uses, and do not provide a good sense of specific activity patterns or overall levels of activity at study locations.

4.5. Characteristics of Study Locations

Door counts and intercept surveys were collected at 30 study locations in smart-growth areas (Table 2). The 30 study locations were contained within 23 unique sites (17 sites had one targeted use, five sites had two targeted uses, and one site had three targeted uses). Therefore, some targeted land use study locations shared the same building, site, and surrounding area characteristics. For example, the first site listed in Table 2, 343 Sansome, is a 257,000 GSF office building (land use code 710) with a coffee shop (land use code 936) on the ground floor. Both uses were counted and surveyed separately but share many of the same contextual characteristics. Summary statistics describing the characteristics of the entire set of study locations should be interpreted with this in mind.

The study locations represented smart-growth areas in the following urban regions in California: Los Angeles, San Francisco, and Sacramento (Figure 1). A variety of development types were represented, including:

- Central business districts

- High-density residential developments within urban areas
- Office developments within urban areas
- Commercial retail developments within urban areas
- Mixed-use developments within urban areas
- Transit-oriented developments

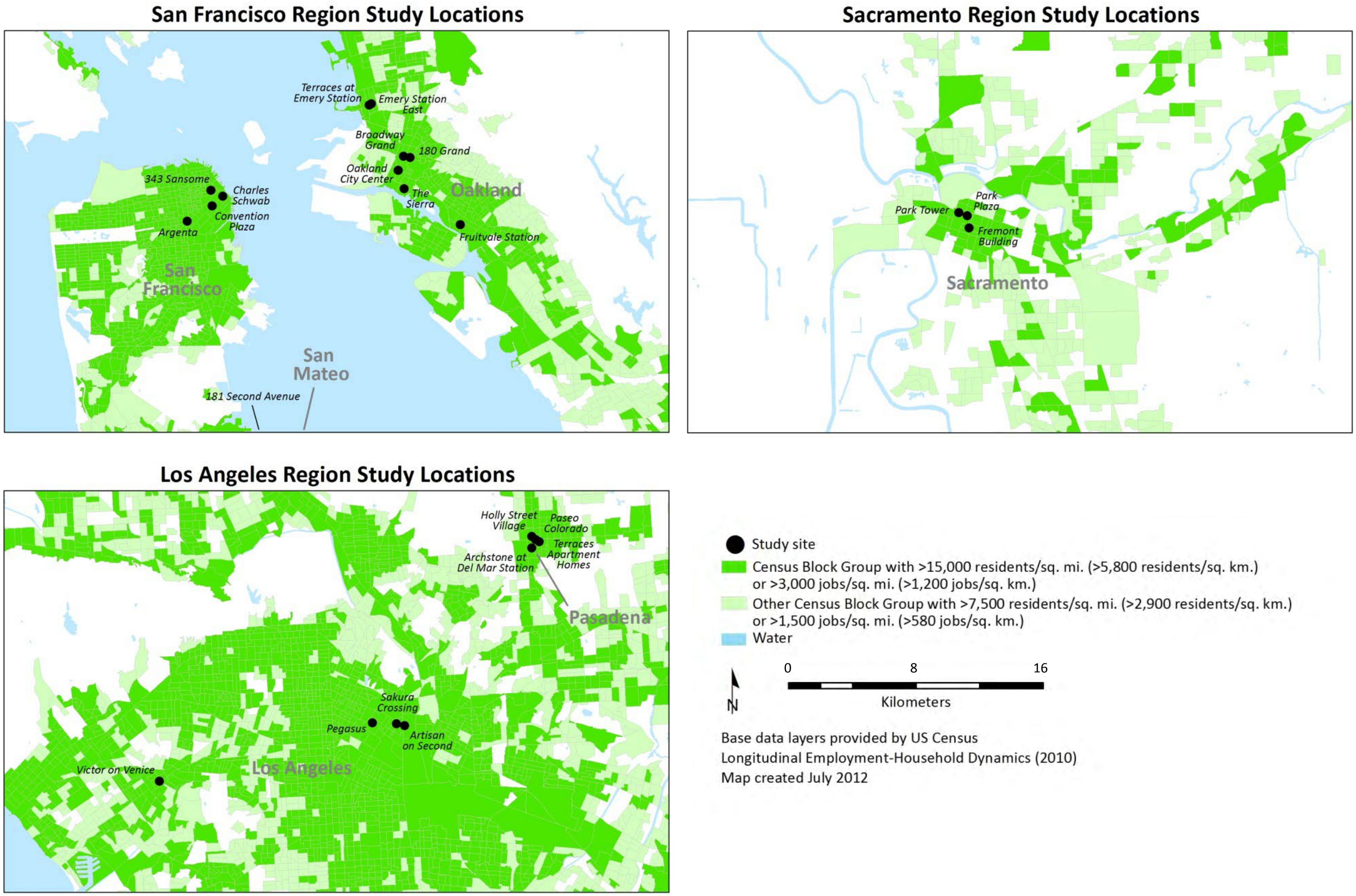
Appendix A includes detailed descriptions of individual study locations.

Table 2. General Characteristics of Study Locations

Location Information				Targeted Land Uses (ITE Use Code)[1]				Targeted Use Size and Occupancy[2]					Surrounding Area Characteristics						
ID	**Site Name**	**Primary Address**	**City**	**Mid- to High-Density Residential**	**Office**	**Commercial Retail Goods**	**Coffee/Donut Shop**	**Residential Units**	**Residential Occupancy**	**Office GSF**	**Office Occupancy**	**Retail GSF**	**Jobs within 0.5 mi. (804 m)[3]**	**Residents within 0.5 mi. (804 m)[3]**	**% Residents within 0.5 mi. (804 m) younger than 15[3]**	**% Residents within 0.5 mi. (804 m) older than 64[3]**	**% Housing units within 0.5 mi. (804 m) that are renter-occupied[3]**	**Rail transit within 0.5 mi. (804 m)[4]**	**Bicycle facilities within 2 blocks[5]**
1.1	343 Sansome	343 Sansome Stret	San Francisco		710					256,985	89%		136,400	18,500	7.2%	24.5%	76.4%	Yes	No
1.2	343 Sansome	343 Sansome Stret	San Francisco				936					1,097	136,400	18,500	7.2%	24.5%	76.4%	Yes	No
2.1	Oakland City Center	1333 Broadway	Oakland		710					239,821	80%		46,400	14,100	7.6%	20.5%	77.9%	Yes	No
2.2	Oakland City Center	1333 Broadway	Oakland				936					*1,100*	46,400	14,100	7.6%	20.5%	77.9%	Yes	No
2.3	Oakland City Center	1333 Broadway	Oakland			880						*11,000*	46,400	14,100	7.6%	20.5%	77.9%	Yes	No
3.1	Fruitvale Station	3100 E. 9th Street	Oakland			867						30,037	3,800	6,600	20.3%	8.7%	63.8%	Yes	No
3.2	Fruitvale Station	3100 E. 9th Street	Oakland				936					1,329	3,800	6,600	20.3%	8.7%	63.8%	Yes	No
4.1	Sakura Crossing	235 S. San Pedro Street	Los Angeles	223				230	96%				66,000	13,300	3.3%	13.5%	76.3%	Yes	No
5.1	Artisan on 2nd	601 E. Second Street	Los Angeles	223				118	96%				27,000	7,100	5.3%	15.0%	65.2%	Yes	No
6.1	Victor on Venice	10001 Venice Boulevard	Los Angeles	223				116	95%				5,300	15,800	10.4%	5.7%	85.2%	No	No
7.1	Pegasus	612 S. Flower Street	Los Angeles	222				322	96%				78,700	12,600	7.0%	16.8%	76.4%	Yes	No
8.1	Paseo Colorado	280 E. Colorado Boulevard	Pasadena			820						497,564	22,600	8,500	9.1%	10.5%	77.4%	Yes	No
9.1	The Sierra[6]	311 Oak Street	Oakland	223				224	98%				12,900	6,000	8.9%	17.5%	70.6%	Yes	No
10.1	180 Grand Avenue[7]	180 Grand Avenue	Oakland		710					277,789	63%		19,200	13,200	7.5%	17.9%	78.8%	Yes	Yes
11.1	Archstone at Del Mar Station[6]	265 Arroyo Parkway	Pasadena	223				235	94%				16,400	7,700	7.5%	12.5%	72.0%	Yes	No
12.1	Terraces at Emery Station	5855 Horton Street	Emeryville	223				101	*100%*				10,300	6,900	10.1%	9.3%	58.4%	Yes	Yes
13.1	Holly Street Village	151 E. Holly Street	Pasadena	223				374	95%				22,700	7,900	12.0%	10.4%	77.7%	Yes	No
14.1	Emery Station East	5885 Hollis Street	Emeryville		710					247,619	*95%*		9,600	7,500	11.0%	8.9%	58.7%	Yes	Yes
15.1	Broadway Grand	438 W. Grand Avenue	Oakland	223				130	82%				20,500	11,700	8.9%	19.8%	81.1%	Yes	Yes
15.2	Broadway Grand	438 W. Grand Avenue	Oakland				936					*1,300*	20,500	11,700	8.9%	19.8%	81.1%	Yes	Yes
16.1	Terraces Apartment Homes	375 E. Green Street	Pasadena	223				276	94%				23,300	9,900	8.4%	10.8%	75.1%	Yes	No
17.1	181 Second Avenue	181 2nd Avenue	San Mateo		710					50,600	99%		7,000	10,900	13.5%	18.9%	62.2%	Yes	No
18.1	Argenta	1 Polk Street	San Francisco	222				187	95%				61,500	25,700	7.6%	10.8%	77.8%	Yes	Yes
19.1	Charles Schwab Building	211 Main Street	San Francisco		710					417,245	77%		87,300	10,100	5.1%	8.0%	52.3%	Yes	Yes
20.1	Park Tower[7]	980 9th Street	Sacramento		710					462,476	90%		54,900	4,400	3.7%	12.8%	73.1%	Yes	No
20.2	Park Tower[7]	980 9th Street	Sacramento				936					1,652	54,900	4,400	3.7%	12.8%	73.1%	Yes	No
21.1	Fremont Building	1501 16th Street	Sacramento	223				69	96%				45,000	6,200	4.2%	9.7%	80.2%	Yes	Yes
22.1	Convention Plaza[7]	201 3rd Street	San Francisco		710					323,000	96%		114,800	13,800	4.3%	20.6%	63.6%	Yes	Yes
22.2	Convention Plaza[7]	201 3rd Street	San Francisco				936					1,556	114,800	13,800	4.3%	20.6%	63.6%	Yes	Yes
23.1	Park Plaza	1303 J Street	Sacramento		710					72,649	88%		55,400	5,100	4.5%	9.5%	77.0%	Yes	No
Total study locations in general use category				12	9	3	6	Average of 23 sites					41,200	10,600	8.0%	14.3%	73.3%		

1) ITE Use Codes are from the ITE Trip Generation Manual, Eighth Edition.
2) Size and occupancy of targeted land uses were generally provided by property managers at the site. Italicized numbers indicate that size or occupancy was estimated from site visit.
3) Housing and employment data are from 2010 US Census.
4) Rail transit includes heavy rail, metro rail, and light rail.
5) 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.
6) Parking garage included parking for a few office tenants in the building.
7) At 180 Grand Avenue, designated parking was located across a public street (23rd St.) from the building, and at Convention Plaza, designated parking was located across a named public alley (Tehama St.) from the building. Both of these study locations were considered to have off-site parking. At Park Tower, designated parking was located across an unnamed alley from the building, so it was considered to have on-site parking.

Figure 1. Study Locations



4.6. Site Layouts

Development sites in smart-growth areas often have multi-use buildings with internal doorways, multi-story parking garages, parking lots shared among several nearby land uses, and a mix of public and private parking. These site layout characteristics were critical to understand in order to obtain an accurate count of the trips generated by each mode at each study location. Different layouts required different approaches to data collection. Common site layouts observed at the study locations are described below.

Type 1. Multi-Building Site

Multi-building sites had one trip generation rate calculated for a single property with several different buildings. Data collection at these sites involved counts and surveys at each access point on the boundary of the site. These access points included driveways, external building doorways, and parking garage entrances and exits. Examples of this type of site include:

- Paseo Colorado

Type 2. Targeted Use with No Parking Lot

Some targeted land uses did not have a direct connection to a parking lot. These targeted uses were typically in urban core areas with high-density residential or commercial development. Data collection at these study locations involved doing counts and surveys at the doors to the targeted use. Unless there was a transit stop within the site containing the targeted use, all people who traveled to this type of study location were recorded as walking for at least part of their inbound or outbound trip (although walking was only considered to be the primary trip mode if the person walked for the entire trip distance).

Examples of this type of site include:

- Charles Schwab Building
- 180 Grand Avenue
- Oakland City Center
- Convention Plaza

Type 3. Targeted Use with Private Parking Lot

Other targeted uses were served by their own private parking lot. This could be a surface parking lot or a parking garage. Where possible, data were collected at all doorway access points to the targeted use (including access points from different levels of a multi-story parking garage). However, if the property manager did not provide permission to survey inside the parking garage or at other locations on private property, data collectors stood at direct public access points to the targeted use and public access points to the parking lot. Respondents who parked in the private parking lot were considered to be using an automobile to access the targeted use. They were not recorded as walking for the part of their trip between their parked car and the doorway. Examples of this type of site include:

- Sakura Crossing
- Artisan on 2nd
- Victor on Venice
- Pegasus

- Holly Street Village
- Terraces Apartment Homes
- Broadway Grand
- Fremont Building
- Park Plaza

Type 4. Targeted Use within Site with Shared Parking

A few targeted uses were part of larger sites that shared parking between uses or provided public parking. This could be a surface parking lot or a parking garage. Where possible, data were collected at doorway access points to the targeted use. However, if the property manager did not provide permission to survey inside the parking garage or at other locations on private property, data collectors stood at direct public access points to the targeted use and public access points to the parking lot. In most cases, respondents who parked in the parking lot at this type of study location were considered to be using an automobile to access the targeted use, regardless of where they parked on the site. However, if a respondent parked in the parking lot and visited a different use on the site before he or she went to the targeted use, he or she was recorded as walking to the targeted use. The same rule was applied in reverse for the outbound trip from the targeted use. People who accessed the parking lot or a different use on the site but did not access the targeted use were not counted in the analysis phase of the study. Examples of this type of site include:

- 343 Sansome
- The Sierra
- Fruitvale Station
- Terraces at Emery Station
- Emery Station East
- 181 Second Avenue
- Argenta
- Park Tower
- Archstone at Del Mar Station

Type 5. Targeted Use in Multi-Use Building with Internal Connections

In some cases, the targeted use was connected to other uses in the same building through internal doorways. Data collection at these study locations involved doing counts and surveys at the doors to the targeted use. This included internal building doorways connecting from other uses to the targeted use. If a respondent traveled between the targeted use and another use in the building through an internal doorway, he or she was recorded as walking for this trip. It is possible for multi-use buildings to have no parking, private parking, or shared parking. Examples of this type of site include:

- 343 Sansome
- Park Tower

5. FIELD DATA COLLECTION

Trip generation information was collected in the field at the 30 study locations during spring 2012. Field data collection involved a combination of door counts and intercept surveys. These two aspects of the data collection process are described in detail below. The final parts of this section describe the data collector training process, field work, and data entry.

5.1. Door Counts

The core field data collection component at each study location was a count of all people entering and exiting the site or targeted land use. This count provided the total number of person-trips generated at each study location during the afternoon peak period.

Door counters tallied all people passing through the doorways (except people who took out garbage, took a smoke break in front of the building, or other people who obviously entered and exited without going to another activity location). People entering each door were counted separately from people exiting. Gender was also recorded. This allowed the research team to identify whether either gender was underrepresented in the intercept survey. Gender bias was later corrected by weighting the survey results. Finally, the door counts were tallied in five-minute increments. This made it possible to identify trip generation peaking patterns within shorter time intervals (e.g., the afternoon peak hour could be identified as 4:25 p.m. to 5:24 p.m. rather than 4:30 p.m. to 5:29 p.m.). The door count form is provided in Appendix B.

Staffing requirements and data collector positioning were identified in advance of the data collection period at each study site. Slightly different strategies were used to gather accurate counts at sites with different layouts:

- At multi-building sites, counts were taken at all access points on the boundary of the site. These site boundary counts included all people entering and exiting the site. People traveling together in the same automobile were counted individually.
- At most targeted land uses, counts were taken at all doorways providing access to that use. This included internal doorways connecting the targeted use to the parking garage or other uses within a building.
- At several targeted land uses it was not possible to count people at doorways leading directly to the targeted use. This occurred at multi-use buildings where permission was not provided to count at internal locations within the building, such as at doors leading from a parking garage directly to the targeted land use. In these study locations, counts were taken at external doorways, such as parking garage entrances and exits. However, these counts included people going to or coming from any use in the building (or other nearby locations if the garage was public), not just people who accessed the targeted use. Therefore, survey respondents intercepted at the external doorways were asked to indicate whether or not they actually visited the targeted use, and this information was used to adjust the count data to reflect the number of trips to and from the targeted use. In the future, it may be easier to only collect data at study locations where doors to targeted land uses can be observed directly (i.e., do not collect data at

potential study locations unless the property manager allows counts and surveys to be administered within the building or parking garage).

- There were no study locations where transit stops were located within the site or targeted use. In these types of locations, it would be necessary to count all passengers as they boarded or exited the bus or train. However, for comparison to standard automobile tube counts, buses would also need to be counted as single vehicles.

The total count of person-trips at each door was allocated by travel mode using intercept survey data collected at that door. It was not possible to obtain complete surveys from every person entering and exiting a study location, so the door counts were critical to providing the best-possible estimate of the correct trip generation rate.

5.2. Intercept Surveys

In-person intercept surveys were offered to a sample of people as they exited doors at each study location. These surveys were designed to determine 1) the mode, time of day, origin, and length of inbound trips to the study location and 2) the mode, time of day, destination, and length of outbound trips from the study location. The travel mode and time of day for each trip were the most important pieces of information on the survey since they were used to allocate the afternoon peak-hour door counts by travel mode. These intercept surveys also collected information about vehicle occupancy so that the person-trip counts for automobile users could be compared to ITE vehicle-based trip rates.

Age, gender, and home zip code were included on the survey to identify socioeconomic characteristics of participants. Comparing the gender of survey respondents to the gender of people counted at doors made it possible to account for any potential gender bias in the sampling procedure. Trip origins and destinations, trip length, respondent age, and respondent zip code can all be used for future travel behavior analysis. Finally, the survey form also included space for data collectors to note the time of survey refusals as well as estimates of the gender and approximate age of individuals who refused to participate. The standard survey form is shown in Appendix C. There was space for four different respondents to provide inbound and outbound trip information on a single page.

Specific survey locations and staffing requirements were identified by the project team in advance of field data collection. The surveyors typically stood 10 to 20 feet outside each doorway at a targeted use and invited the first person to exit at the beginning of the three-hour study period to take the survey[18]. At most study locations, a single surveyor covered each door, but two or three surveyors were used at several high-activity doors. After a survey was completed, data collectors asked the next person exiting the doorway to participate. Other people who exited while data collectors were busy administering surveys were not offered a chance to participate. In addition, some people who were invited to take the survey declined

[18] Data collectors were allowed to offer exit surveys from inside the building at two of the study locations. This did not affect the survey responses.

to participate. While these people did not participate in the survey, they were recorded by the door counters at the survey location.

The full survey typically took 30 to 60 seconds for respondents to complete. If a respondent made multiple trips to and from the study location during peak-hour travel periods that day, the survey tended to take slightly longer than 60 seconds. The duration of surveys was estimated from informal observations made by data collection managers at several study locations on different days.

Some potential respondents were in a hurry as they exited study locations, so they did not want to stop to do the full survey. Many of these people refused to participate. However, some of them were willing to share information quickly as they walked by. An abbreviated version of the survey was used in this situation. This abbreviated version asked only two questions about the respondent's current trip: "How are you getting there?" and "Where are you going?" This option was typically completed in 10 to 15 seconds. The mode of transportation for the respondent's current trip was the only absolutely essential information needed to constitute a usable survey for the purpose of this study. Therefore, partial survey responses provided useful information, even though they did not include many details.

Exit surveys were used rather than entry surveys for several reasons:

- Survey participants could be selected randomly. Surveyors did not have an option to choose people who they thought would be more likely to participate in the survey; they were trained to always invite the next person who exited the door.
- Entry surveys had several disadvantages. It was more difficult to get permission for surveyors to stand inside the building and intercept people as they entered doorways. If the surveyors stood outside (typically on public property or in a common area), it was difficult to determine which people were going to the targeted use and which people were just walking by. In addition, at locations where surveys were offered at parking garage access points, it would have been onerous for drivers to stop while entering from the street. It was much easier to stop drivers at an exit as they approached the public sidewalk crossing.

During the survey, respondents were asked where they were going (outbound trip) before they were asked where they came from (inbound trip) for three reasons:

- People were expected to be able to answer the question easily. They would be aware of where they were going at the time of the survey and would not need to try to recall a trip made several minutes or hours earlier.
- The mode of the current trip was the only absolutely essential piece of information that was needed from a respondent, so this survey design made it possible to obtain that information in the first question. In many cases, hurried respondents were also able to respond with the name of the intersection closest to where they were going next before walking, bicycling, or driving away. These abbreviated surveys were still useful for the main purpose of the research project.

- Asking about travel mode first helped engage respondents. By quickly asking, "What type of transportation are you using now?" or using the modified wording, "Can you tell me about your commute home?" or "Can you tell me about your travel for 15 seconds for Caltrans?", the surveyors were able to generate immediate interest in the survey.

Depending on the site layout, characteristics of the exit point, and the type of targeted land use where surveys were being offered, the survey sometimes flowed better when the surveyor put questions into chronological order or into his or her own words. These adjustments may have helped improve respondent comprehension and increase overall response rates slightly. Data collection managers could consider reordering and phrasing questions differently in the future at certain study locations. Advance training is also critical for making sure surveyors understand the type of information that should be recorded and letting them know that they have flexibility to diverge from the survey script.

While the survey form could be used to capture multiple trips to and from the study location from a single respondent (by recording additional trips in a second row), very few respondents reported more than a single inbound and a single outbound trip. It is possible that many people only made one trip to and one trip from the site during the morning or afternoon peak hours. However it is also possible that surveyors did not have a chance to ask any follow-up questions to gather these additional trips. Therefore, trips made earlier in the day may have been more likely to be omitted from the responses. However, there were still a sufficient number of trips reported during the AM study period to analyze morning peak-hour trip generation at most study locations.

Surveyors and door counters were stationed at parking garage access points at some study locations. This was done at buildings where property management did not allow data collection in the parking garage or other locations inside the building. These parking garages often served multiple uses (not just the targeted use). Therefore, the surveys were essential for determining the proportion of people exiting that actually accessed the targeted use. Parking garage entrance surveys used a slightly modified approach. Intercept surveyors wearing orange and yellow vests stood on the driver's side of the garage exit point (at or just in advance of where the garage driveway crossed the public sidewalk). When a car approached, they motioned to drivers to roll down their window and take the abbreviated version of the survey. The mode question was straightforward (automobile), so the only other critical survey information was whether or not the respondent actually visited the targeted use. Most drivers also stopped long enough to provide their trip destination and home zip code. The total number of people in the automobile was observed and driver age and gender were estimated to save time. These parking garage surveys usually took 10 to 15 seconds. In order to prevent congestion and driver frustration, surveyors did not ask drivers to stop for the survey if there were other cars immediately behind approaching the garage exit.

Future applications of the survey methodology should test different orders of questions and different types of survey forms. The ideal survey form should be adaptable to full-length or abbreviated surveys and be easy to understand in either case. Other suggestions for future multimodal trip generation intercept surveys include:

- Provide in-depth training to surveyors. Focus on understanding the definition of an inbound trip and an outbound trip (some surveyors initially interpreted the "trip you took to get here" as the 10- to 20-foot movement from the door of the study location to the surveyor—rather than the trip they had taken to get to the study location).
- During training, clarify that surveyors should not try to guess the mode of transportation people are using if they refuse to participate in the survey. To be participant in the survey, a person must at least give a verbal answer to the type of transportation that he or she is using on his or her current trip. Otherwise, they should be marked as a refusal. Surveyors should not try to guess the mode being used, even if they are able to watch a person who refused the survey walk the whole way to his or her next activity or get on the bus at an adjacent bus stop. Even though the surveyor could record the mode used in the examples above “correctly”, those trips would not be sampled in the same way as trips from other respondents. This is a problem because there is no way to correctly guess the mode of a person who walks to parking or walks to a transit stop that is out of sight. If non-respondents whose mode could be observed “correctly” were included, the modes that could be observed directly would be oversampled, which would introduce bias into the results.
- Add a short question to the survey to determine whether or not the person actually accessed the targeted use. This is needed at doorways that may be used by people from other uses in the building or surrounding area besides the targeted use.
- Surveyors should use the time in between surveys to make sure their handwriting is clear, spell out abbreviations, and clarify any markings or notes that could help make data entry easier. This is especially important because someone other than the data collector often enters the data.
- Data collection managers should review survey responses recorded over the first 30 minutes of a data collection period to correct any systematic errors being made by the surveyors. At sites with morning surveys and afternoon surveys, data collection managers should review the morning surveys to catch common errors and discuss them with the surveyors before they start afternoon data collection.
- Try to get permission to survey at doors that provide direct access to targeted land uses rather than at shared parking garage entrances. Surveying all people exiting parking garages just to obtain data from a certain proportion of people who accessed a particular use on a site is less efficient than surveying at direct access points (because surveyor time is spent collecting non-usable survey data). It also introduces another analysis step and its associated error into the final trip generation calculations. When the methodology is used in the future, data collection managers may want to make a rule that targeted uses should not be studied unless the property manager provides full permission to survey at all direct access points to the targeted use.

5.3. Recruitment and Training

Professional data collection companies were used to conduct intercept surveys. Temporary agency personnel were hired to conduct counts at doorways. After recruiting professional data collection companies, the research team discussed details of the counting and survey processes with managers at these companies. The intercept surveys required an outgoing personality. The interviewers provided by the data collection companies were generally friendly, assertive, willing to approach and talk to strangers, looked professional, and understood the purpose and procedure for the interviews.

The first day of data collection was treated as a pilot test of the proposed procedures. While the final survey and door count forms were revised based on this initial test, data from the pilot site were consistent with other sites and were included in the final analysis. Key points made to door counters and intercept surveyors during training at the pilot site and throughout the data collection process are listed in Appendix D.

5.4. Data Collection at Study Locations

Several days in advance of field data collection at each study location, the project team data collection managers prepared a map of locations where counts and intercept surveys were to be performed. Maps also included the names of buildings, stores, and areas to which survey respondents might refer.

On data collection days, door counters and intercept surveyors were oriented to the site at least 15 minutes prior to the beginning of the data collection period. Arriving early allowed data collectors to observe the site layout, familiarize themselves with their particular survey or count location, and use the restroom, if necessary. Prior to the start of a data collection period, the data collection manager asked each data collector if he or she had any questions and made sure instructions were clear. The data collection manager also confirmed that counters know which movements would be noted and where the counts should be recorded on the form. After data collection began, the supervisor circulated among the counters and surveyors to ensure data were being collected correctly.

The data collection managers monitored the real-time progress of the counts and intercept surveys and made adjustments as necessary to achieve a sufficient sample. Adjustments included redeploying surveyors to different locations that had more activity. In some cases, individual data collectors were told to switch locations in order to minimize socializing or improve perceptions of personal security.

At a few study locations, there was an extra door counter or surveyor. These personnel were rotated among the doorways where counts or surveys were being taken to give short breaks to other data collectors. Most study locations did not have extra data collectors, so the data collection manager stepped in to provide relief to the data collectors.

Data collection at most locations went smoothly, and there were no complaints from property managers, survey respondents, or other people at the study location. A few property managers received complaints during morning data collection from tenants or customers who did not want to be asked to participate in a survey. There were also a few study locations where the data collection managers thought that the property manager had provided permission to survey on private property or inside a parking garage, but the property manager was not comfortable with this. In these cases, the data collection manager worked with the property manager to make any adjustments to ease these concerns (e.g., changing where data collection personnel were standing with respect to the doorway or moving data collectors to public property). Managers performed initial data quality checks in the field (Appendix E).

5.5. Data Entry and Quality Control

The paper door count and intercept forms were entered into electronic spreadsheets by members of the research team. Since data entry was an extensive, detailed, multi-week process, quality control checks were important. Every tenth door count form and every tenth intercept survey page was checked for data entry errors. This review showed that more than 99.9% of the checked door count data cells were entered correctly and more than 99.5% of the survey data items were entered correctly. All minor errors found were corrected.

5.6. Data Summary

Overall, the door counters recorded a total of 31,515 individual entries and exits. The surveyors approached a total of 5,501 people. Of these people, 3,371 (61%) provided at least a basic response with their current travel mode (2,129 refused to participate and one did not provide a travel mode). The 3,371 respondents reported a total of 5,170 trips. Table 3 summarizes the data collected at each study location by day and time period.

A survey was determined to be usable if the respondent provided the travel mode for at least one trip. The overall trip mode share at each study location was calculated from a sample of trips reported by survey respondents. Therefore, it was important for this sample to be large enough to provide a good estimate of the actual trip mode share.

The number of usable surveys collected at each study location depended on overall activity levels and response rates at each site. While the overall response rate was greater than 60%, people gave a variety of reasons for not participating in the survey. During the course of field work, non-respondents said that they were in a hurry, did not want to be bothered, were trying to catch public transportation, or thought that the intercept surveyors were asking for money or signatures for a political cause.

Table 3. Summary of Data Collected at Study Locations

							AM Data Collection (7 a.m.-10 a.m.)								PM Data Collection (4 p.m.-7 p.m.)							
	Targeted Land Uses (ITE Use Code)[1]							Door Counts			Intercept Surveys					Door Counts			Intercept Surveys			
Site Name	Mid- to High-Density Residential	Office	Commercial Retail Goods	Coffee/Donut Shop	Data Collection Date	Advance notice[2]	Weather	Male	Female	Total	Refusals	Complete[3]	Usable[4]	Response rate[5]	Weather	Male	Female	Total	Refusals	Complete[3]	Usable[4]	Response rate[5]
Pegasus	222				Wed., May 2, 2012	No	55, Cloudy	180	136	**316**	84	46	**54**	**39.1%**	57, Cloudy	156	140	**296**	28	21	**23**	**45.1%**
Sakura Crossing	223				Tue., May 1, 2012	Yes	55, Cloudy	105	118	**223**	3	64	**152**	**98.1%**	55, Cloudy	185	128	**313**	15	34	**57**	**79.2%**
Argenta	222				Wed., May 16, 2012	No	52, Cloudy	170	82	**252**	74	37	**38**	**33.9%**	55, Cloudy, Windy	187	88	**275**	30	45	**57**	**65.5%**
Fremont Building[6]	223				Tue., May 1 & May 22	No	67, Sunny	49	41	**90**	10	29	**38**	**79.2%**	70, Sunny	38	51	**89**	1	10	**16**	**94.1%**
Artisan on 2nd	223				Tue., May 1, 2012	Yes	55, Cloudy	77	69	**146**	30	45	**47**	**61.0%**	55, Cloudy	76	60	**136**	9	20	**26**	**74.3%**
Terraces Apartment Homes[7]	223				Thu., May 10, 2012	Yes	60, Sunny	124	97	**221**	1	96	**117**	**99.2%**	65, Sunny	97	85	**182**	3	48	**72**	**96.0%**
Holly Street Village[8]	223				Wed., May 9, 2012	Yes	70, Sunny	170	179	**349**	8	98	**166**	**95.4%**	75, Sunny	213	217	**430**	1	62	**104**	**99.0%**
Broadway Grand	223				Thu., May 10, 2012	No	65, Sunny	74	86	**160**	20	55	**73**	**78.5%**	77, Sunny	97	102	**199**	17	31	**43**	**71.7%**
Archstone at Del Mar Station	223				Tue., May 8, 2012	Yes	65, Sunny	138	64	**202**	23	88	**122**	**84.1%**	75, Sunny	148	85	**233**	9	49	**62**	**87.3%**
The Sierra[9]	223				Tue., May 8, 2012	Yes	65, Sunny	170	137	**307**	41	90	**102**	**71.3%**	77, Sunny	219	178	**397**	28	67	**79**	**73.8%**
Terraces at Emery Station[10]	223				Wed., May 9, 2012	No	62, Sunny	427	339	**766**	85	89	**103**	**54.8%**	65, Sunny, Windy	388	318	**706**	14	77	**136**	**90.7%**
Victor on Venice	223				Wed., May 2, 2012	Yes	55, Cloudy	95	61	**156**	0	49	**79**	**100.0%**	57, Cloudy	105	85	**190**	1	25	**41**	**97.6%**
343 Sansome[11]		710			Thu., Mar. 29, 2012	No	55, Cloudy	397	256	**652**	40	8	**8**	**16.7%**	60, Cloudy	356	250	**606**	159	65	**66**	**29.3%**
Convention Plaza[12]		710			Wed., May 23, 2012	No	57, Sunny	539	485	**1024**					62, Sunny	534	465	**999**	179	92	**112**	**38.5%**
Charles Schwab Building		710			Wed., May 16, 2012	No	52, Cloudy	502	528	**1030**					55, Cloudy, Windy	393	429	**822**	65	129	**173**	**72.7%**
Park Plaza		710			Thu., May 24, 2012	Yes	65, Sunny	58	54	**112**					75, Sunny	34	61	**95**	11	34	**44**	**80.0%**
Park Tower		710			Tue., May 22, 2012	Yes	67, Sunny	770	728	**1498**					82, Sunny	548	468	**1016**	130	243	**270**	**67.5%**
Oakland City Center		710			Tue., Apr. 24, 2012	No	60, Sunny	235	251	**486**					75, Sunny	212	225	**437**	102	54	**71**	**41.0%**
180 Grand Avenue		710			Tue., May 8, 2012	Yes	65, Sunny	200	217	**417**					77, Sunny	139	179	**318**	114	53	**63**	**35.6%**
Emery Station East		710			Thu., May 10, 2012	No	65, Sunny	384	213	**597**					77, Sunny	350	189	**539**	62	85	**151**	**70.9%**
181 Second Avenue		710			Tue., May 15, 2012	Yes	62, Sunny	69	100	**169**					70, Sunny	125	126	**251**	35	52	**62**	**63.9%**
Oakland City Center			880		Tue., Apr. 24, 2012	No	60, Sunny	368	506	**874**					75, Sunny	554	667	**1221**	95	24	**24**	**20.2%**
Paseo Colorado			820		Thu., May 3, 2012	No	55, Partly Cloudy								62, Partly Cloudy	1664	2463	**4128**	163	126	**153**	**48.4%**
Fruitvale Station			867		Thu., Apr. 26, 2012	No	55, Sunny	62	57	**119**					65, Sunny, Windy	127	137	**264**	45	23	**23**	**33.8%**
343 Sansome[11]				936	Thu., Mar. 29, 2012	No	55, Cloudy	398	354	**752**	99	41	**41**	**29.3%**	60, Cloudy	83	70	**153**	22	3	**3**	**12.0%**
Convention Plaza[13]				936	Wed., May 23, 2012	No	57, Sunny	360	332	**692**	35	25	**25**	**41.7%**	62, Sunny	117	68	**185**	18	22	**23**	**56.1%**
Park Tower				936	Tue., May 22, 2012	No	67, Sunny	506	521	**1027**	59	57	**84**	**58.7%**	82, Sunny	79	95	**174**	10	29	**32**	**76.2%**
Oakland City Center				936	Tue., Apr. 24, 2012	No	60, Sunny	573	587	**1160**					75, Sunny	234	243	**477**	53	15	**16**	**23.2%**
Broadway Grand[14]				936	Thu., May 10, 2012	No	65, Sunny	449	396	**845**	28	55	**69**	**71.1%**	77, Sunny	259	279	**538**	18	28	**28**	**60.9%**
Fruitvale Station				936	Thu., Apr. 26, 2012	No	55, Sunny	433	311	**744**					65, Sunny, Windy	255	206	**461**	52	23	**23**	**30.7%**
							AM Totals	**8081**	**7304**	**15386**	**640**	**972**	**1318**	**67.3%**	**PM Totals**	**7972**	**8157**	**16129**	**1489**	**1589**	**2053**	**58.0%**

1) ITE Use Codes are from the ITE Trip Generation Manual, Eighth Edition.
2) Some property managers provided advance notice to tenants or patrons at study locations to let them know that data collection would be conducted. Advance notice was provided through e-mail, paper fliers posted on community bulliten boards, fliers distributed to each unit, and meetings with tenants.
3) A survey was determined to be complete if the respondent provided the travel mode and an origin or destination location for at least one trip.
4) A survey was determined to be useable if the respondent provided the travel mode for at least one trip.
5) The response rate reported in this table is the percentage of all people invited to take the survey who provided a usable response (provided at least the mode used on their current trip).
6) Fremont Building AM data collection was Tue., May 22, and PM data collection was Tue., May 1.
7) PM data collection at Terraces Apartment Homes was from 3:30 p.m. to 6:30 p.m.
8) PM data collection at Holly Street Village was from 3:30 p.m. to 6:30 p.m.
9) A small number of people (3 to 4) parked in the garage on site at the Sierra and were counted at the building doorways before walking to their offices.
10) Many people who parked in the public parking garage and were counted at the Terraces doorways did not go to the Terraces apartments; they walked across the street to the adjacent office.
11) AM data collection at 343 Sansome was from 6:30 a.m. to 9:30 a.m.; PM data collection at 343 Sansome was from 4:00 p.m. to 6:30 p.m.
12) Main lobby entrance was closed due to construction, so all office workers used same door on Third Street. This did not appear to affect the overall activity level at the study location.
13) Entrance route was partially blocked due to construction, but there was good signage directing customers to Starbucks. This did not appear to affect the overall activity level at the study location.
14) Data collector stood directly outside Starbucks door in AM; Data collector alternated between standing ~50 feet (15 m) west and ~50 feet (15 m) east of the Starbucks door in the PM data collection period.

6. ANALYSIS

This section describes how the count and survey data were analyzed to estimate trips to and from each study location during the afternoon peak hour. This process involved several steps:

- Quantify the total number of person-trips made during the morning or afternoon peak hour to and from each study location.
- Determine the trip mode share at each door during the three-hour morning or afternoon data collection period.
- Allocate peak-hour person-trips by mode at each door.
- Calculate peak-hour person-trips by mode for the full study location.

Step 1. Quantify Total Peak-Hour Person-Trips at the Study Location

People were counted entering and exiting doors over five-minute intervals throughout the three-hour morning or afternoon study period at each study location. These door counts were summed to quantify the total number of person-trips generated by the targeted land use.

At a few locations, data collectors arrived late, so the counts at their doors were estimated based on the share of the total study location count represented by their doors during later time periods.

At some sites, counts were taken at doors to a garage that allowed public parking. In these locations, a portion of the people counted at the garage doors did not access the targeted land use (e.g., they accessed another land use within the building, accessed another land use nearby, or just passed through the garage). Survey responses were used to identify and subtract the people who did not access the targeted use at each door.

Next, the number of peak-hour person-trips was quantified at each study location (Table 4). Examples of peaking patterns at two study locations are shown in Figure 2.

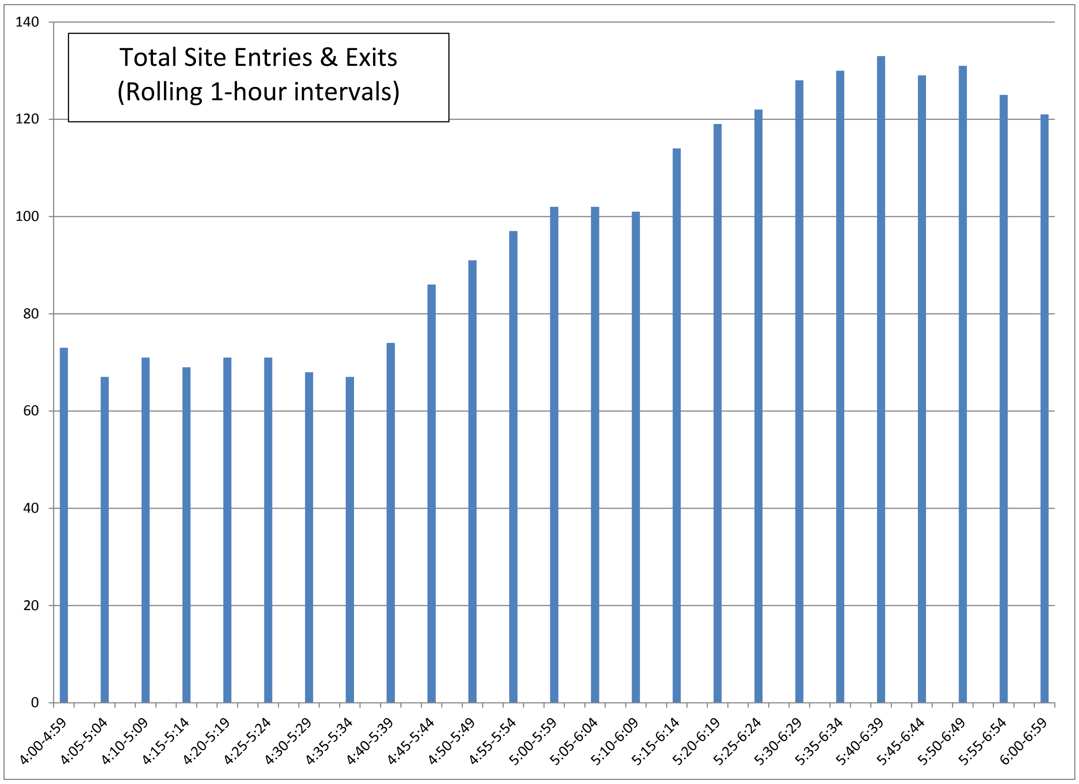
Table 4. Peak-hour Person-Trips Generated by Study Location

	Targeted Land Uses (ITE Use Code)[1]				AM Study Period (7 a.m.-10 a.m.)							PM Study Period (4 p.m.-7 p.m.)						
					Peak Hour		Three-Hour Summary					Peak Hour		Three-Hour Summary				
Site Name	**Mid- to High-Density Residential**	**Office**	**Commercial Retail Goods**	**Coffee/Donut Shop**	**Time Period**	**Trips**	Overall Trips[2]	% Male	% Female	% In	% Out	**Time Period**	**Trips**	Overall Trips[2]	% Male	% Female	% In	% Out
Pegasus	222				**8:10-9:09**	**136**	316	57.0%	43.0%	25.3%	74.7%	**5:40-6:39**	**133**	296	52.7%	47.3%	64.9%	35.1%
Sakura Crossing	223				**7:50-8:49**	**106**	223	46.9%	53.1%	19.7%	80.3%	**5:55-6:54**	**152**	313	59.1%	40.9%	58.8%	41.2%
Argenta	222				**7:30-8:29**	**89**	226	67.0%	33.0%	16.3%	83.7%	**5:30-6:29**	**107**	249	68.4%	31.6%	67.8%	32.2%
Fremont Building	223				**7:55-8:54**	**50**	90	54.4%	45.6%	22.2%	77.8%	**5:15-6:14**	**42**	89	43.1%	56.9%	63.4%	36.6%
Artisan on 2nd	223				**9:00-9:59**	**62**	146	52.7%	47.3%	19.9%	80.1%	**6:00-6:59**	**51**	136	55.6%	44.4%	64.0%	36.0%
Terraces Apartment Homes[3]	223				**7:00-7:59**	**88**	221	56.1%	43.9%	31.0%	69.0%	**5:20-6:19**	**85**	182	53.3%	46.7%	53.3%	46.7%
Holly Street Village[4]	223				**7:00-7:59**	**175**	349	48.7%	51.3%	21.2%	78.8%	**5:05-6:04**	**185**	430	49.5%	50.5%	57.4%	42.6%
Broadway Grand	223				**7:55-8:54**	**72**	160	46.3%	53.8%	25.0%	75.0%	**5:10-6:09**	**85**	199	48.7%	51.3%	58.3%	41.7%
Archstone at Del Mar Station	223				**7:00-7:59**	**98**	202	68.3%	31.7%	18.8%	81.2%	**4:25-5:24**	**102**	233	63.6%	36.4%	54.5%	45.5%
The Sierra	223				**7:30-8:29**	**121**	307	55.4%	44.6%	30.6%	69.4%	**5:15-6:14**	**166**	397	55.2%	44.8%	62.2%	37.8%
Terraces at Emery Station	223				**8:00-8:59**	**159**	391	55.9%	44.1%	54.3%	45.7%	**5:00-5:59**	**138**	447	56.5%	43.5%	40.2%	59.8%
Victor on Venice	223				**8:45-9:44**	**61**	156	60.9%	39.1%	26.3%	73.7%	**5:50-6:49**	**76**	190	55.3%	44.7%	64.7%	35.3%
343 Sansome[5]		710			**8:30-9:29**	**316**	652	60.8%	39.2%	69.8%	30.2%	**4:40-5:39**	**333**	606	58.7%	41.3%	19.0%	81.0%
Convention Plaza		710			**8:15-9:14**	**514**	1024	52.6%	47.4%	88.7%	11.3%	**4:50-5:49**	**491**	999	53.5%	46.5%	17.8%	82.2%
Charles Schwab Building		710			**8:20-9:19**	**510**	1030	48.7%	51.3%	86.4%	13.6%	**4:30-5:29**	**401**	822	47.8%	52.2%	12.5%	87.5%
Park Plaza		710			**8:20-9:19**	**55**	112	51.8%	48.2%	77.7%	22.3%	**4:20-5:19**	**53**	95	35.8%	64.2%	15.8%	84.2%
Park Tower		710			**7:40-8:39**	**617**	1498	51.4%	48.6%	75.2%	24.8%	**4:25-5:24**	**566**	1016	53.9%	46.1%	14.3%	85.7%
Oakland City Center		710			**8:05-9:04**	**248**	486	48.4%	51.6%	73.9%	26.1%	**4:25-5:24**	**221**	437	48.5%	51.5%	23.8%	76.2%
180 Grand Avenue		710			**8:15-9:14**	**184**	417	48.0%	52.0%	78.4%	21.6%	**4:25-5:24**	**143**	318	43.7%	56.3%	17.9%	82.1%
Emery Station East		710			**8:25-9:24**	**298**	597	64.3%	35.7%	83.2%	16.8%	**4:45-5:44**	**251**	539	64.8%	35.2%	17.9%	82.1%
181 Second Avenue		710			**9:00-9:59**	**101**	142	48.5%	70.5%	72.9%	27.1%	**4:25-5:24**	**114**	251	49.6%	50.4%	32.8%	67.2%
Oakland City Center			880		**9:00-9:59**	**341**	874	42.1%	57.9%	49.1%	50.9%	**4:45-5:44**	**479**	1221	45.4%	54.6%	48.2%	51.8%
Paseo Colorado			820									**5:05-6:04**	**1551**	4128	40.3%	59.7%	52.9%	47.1%
Fruitvale Station			867		**8:40-9:39**	**60**	119	52.1%	47.9%	51.3%	48.7%	**4:50-5:49**	**116**	264	48.1%	51.9%	43.9%	56.1%
343 Sansome[5]				936	**8:10-9:09**	**356**	752	52.9%	47.1%	51.9%	48.1%	**4:00-4:59**	**126**	153	54.2%	45.8%	52.4%	47.6%
Convention Plaza				936	**7:30-8:29**	**259**	692	52.0%	48.0%	47.0%	53.0%	**4:00-4:59**	**80**	185	63.2%	36.8%	42.2%	57.8%
Park Tower				936	**9:00-9:59**	**430**	1027	49.3%	50.7%	50.2%	49.8%	**4:10-5:09**	**90**	174	45.4%	54.6%	51.7%	48.3%
Oakland City Center				936	**8:20-9:19**	**485**	1160	49.4%	50.6%	50.5%	49.5%	**4:50-5:49**	**265**	477	49.1%	50.9%	44.9%	55.1%
Broadway Grand				936	**8:00-8:59**	**316**	845	53.1%	46.9%	49.6%	50.4%	**4:00-4:59**	**237**	538	48.1%	51.9%	47.6%	52.4%
Fruitvale Station				936	**8:15-9:14**	**331**	744	58.2%	41.8%	52.0%	48.0%	**5:30-6:29**	**192**	461	55.3%	44.7%	48.8%	51.2%

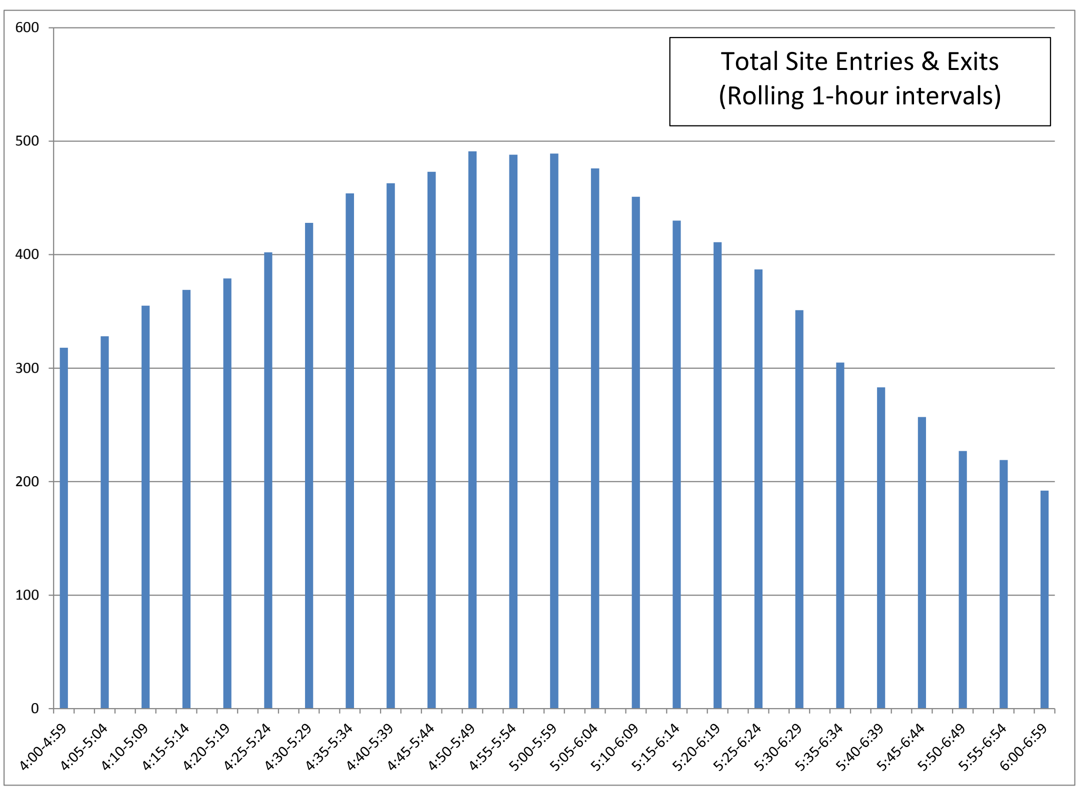
1) ITE Use Codes are from the ITE Trip Generation Manual, Eighth Edition.
2) Overall trips includes all trips to and from the study location during the three-hour study period. Door counts of people who did not access the study location were removed from this total.
3) PM data collection at Terraces Apartment Homes was from 3:30 p.m. to 6:30 p.m.
4) PM data collection at Holly Street Village was from 3:30 p.m. to 6:30 p.m.
5) AM data collection at 343 Sansome was from 6:30 a.m. to 9:30 a.m.; PM data collection at 343 Sansome was from 4:00 p.m. to 6:30 p.m.

Figure 2. Example Afternoon Study Period Door Counts

Pegasus (High-rise residential building, Los Angeles)



Convention Plaza (Office building, San Francisco)



Step 2. Determine Trip Mode Share at Each Door

In order to estimate the travel modes used for morning or afternoon peak-hour person-trips, it was first necessary to determine the modes used by intercept survey respondents at each individual door at a study location. Surveys captured information about the mode of transportation used by a sample of people exiting doorways from each study location. The respondents reported all modes that they used on each trip, including any walking done between an off-site parking space or transit stop and the study location. For all usable surveys, the primary trip mode was assigned based on the following assumptions:

- If a respondent used transit on any part of his or her trip, transit was the primary trip mode. People may drive, walk, or bicycle to or from transit, but if they use transit, they often take it for the longest distance on their trip.
- If a respondent did not use transit but used automobile on any part of his or her trip, automobile was the primary trip mode. People may walk to or from automobile parking, but if they use an automobile, they often use it for the longest distance on their trip.
- If a respondent did not use transit or automobile but used a bicycle on any part of his or her trip, bicycle was the primary trip mode. People may walk to or from bicycle parking, but if they use a bicycle, they often use it for the longest distance on their trip.
- If a respondent walked the whole way on his or her trip, walking was the primary mode.

Table 5 shows the total number of trips (inbound plus outbound) recorded by the intercept surveyors at each study location. Afternoon survey respondents reported some of the morning trips and morning respondents reported some of the afternoon (i.e., previous evening) trips. The exit intercept surveys were not offered in the morning at some locations because they were predominately office or retail uses (e.g., Oakland City Center, Fruitvale Station, Paseo Colorado, Park Plaza), so these locations only had a few morning trips reported by afternoon survey respondents. To be considered for further mode share analysis, a study location was required to have at least 30 surveyed trips during the morning or afternoon study period.

Since the survey was offered only to people exiting each study location, data collectors recorded more outbound trips than inbound trips. However, respondents still reported a sufficient number of inbound trips to include in the analysis (inbound trips accounted for 39% of morning survey trips and 21% of afternoon survey trips used in the analysis). Potential bias from oversampling outbound trips was reduced by weighting the surveyed trips by direction (see explanation below).

Individual doors were analyzed because certain doorways may have had different mode shares than the overall study location (e.g., a door leading to the parking lot may have more automobile users; a door leading to a bus stop may have more transit users). It was necessary to account for these differences to calculate the overall study location mode share correctly.

The mode share at each doorway was calculated from primary trip mode data collected over the full three-hour morning or afternoon survey period. This was done to increase the number of sampled trips used to calculate mode share. If survey responses were taken only from the peak hour, the research team would have had less confidence in the mode share estimate. It is possible that trip mode share at a particular door could change within the three-hour study period, but it was assumed to be constant for the purposes of this study.

Some low-activity doorways were counted but not surveyed. In these locations, person-trips in and out of these doors were counted, but the modes used for their trips were assigned based on other similar doorways at the study location. Mode shares from similar doors were used rather than an average of all doors because this was likely to provide a better estimate of the actual mode share at a particular door. For example, parking garage doors were likely to have a similar mode shares (a high proportion of automobile trips); doors leading to nearby transit stops were likely to have similar mode shares (a high proportion of transit trips).

During this step, survey respondent gender was compared with the count of females and males at each door. If the gender split of survey respondents was different than the door-count gender split, the mode share reported by the underrepresented gender was given a higher weight in the final mode share calculation. This adjustment removed small amounts of gender bias from the surveys. Overall, approximately 51% of people counted at doorways were male and approximately 52% of survey respondents were male. However, there were some individual doorways where survey respondent gender was not as balanced. For example, just under half of the people counted at each of the Oakland City Center office building doorways were male, but males accounted for nearly 75% of the survey respondents. Removing gender bias was important because travel surveys have shown differences in mode share by gender, particularly for bicycling (Cervero and Duncan 2003; Schneider 2011). A similar process was used to adjust the overall mode share at each doorway to account for differences between reported inbound and outbound trip mode shares.

This approach assumes that the mode share of trips entering and exiting a study location over the three-hour study period represents the mode share during the peak hour. It is possible that the mode share is slightly different during peak hours due to different activity patterns and transportation system characteristics (e.g., peak transit service frequency, traffic congestion, variable parking pricing). Future research should explore this issue.

Table 5. Sample of Trips Collected from Intercept Surveys at each Study Location

	Targeted Land Uses (ITE Use Code)[1]				Three-Hour Study Periods	
Site Name	**Mid- to High-Density Residential**	**Office**	**Commercial Retail Goods**	**Coffee/Donut Shop**	**Surveyed AM Trips (7 a.m.-10 a.m.)[2]**	**Surveyed PM Trips (4 p.m. to 7 p.m.)[2]**
Pegasus	222				**54**	**24**
Sakura Crossing	223				**143**	**61**
Argenta	222				**49**	**64**
Fremont Building	223				**40**	**37**
Artisan on 2nd	223				**48**	**33**
Terraces Apartment Homes[3]	223				**121**	**73**
Holly Street Village[4]	223				**177**	**111**
Broadway Grand	223				**79**	**65**
Archstone at Del Mar Station	223				**142**	**70**
The Sierra	223				**111**	**137**
Terraces at Emery Station	223				**48**	**105**
Victor on Venice	223				**93**	**48**
343 Sansome[5]		710			**37**	**72**
Convention Plaza		710			**60**	**110**
Charles Schwab Building		710			**118**	**178**
Park Plaza		710			**25**	**44**
Park Tower		710			**193**	**272**
Oakland City Center		710			**36**	**72**
180 Grand Avenue		710			**46**	**65**
Emery Station East		710			**62**	**153**
181 Second Avenue		710			**41**	**68**
Oakland City Center			880		**1**	**46**
Paseo Colorado			820		**1**	**252**
Fruitvale Station			867		**0**	**41**
343 Sansome[5]				936	**79**	**6**
Convention Plaza				936	**49**	**38**
Park Tower				936	**145**	**44**
Oakland City Center				936	**3**	**16**
Broadway Grand				936	**123**	**49**
Fruitvale Station				936	**1**	**44**
					2125	**2398**

1) ITE Use Codes are from the ITE Trip Generation Manual, Eighth Edition.

2) Surveyed trips includes all reported access and egress trips that occurred during the 3-hour study period window. Note that some AM-period trips were reported by PM respondents and some PM-period trips (e.g., previous evening) were reported by AM respondents. Trips reported by people who did not access the study location were removed.

3) PM data collection at Terraces Apartment Homes was from 3:30 p.m. to 6:30 p.m.

4) PM data collection at Holly Street Village was from 3:30 p.m. to 6:30 p.m.

5) AM data collection at 343 Sansome was from 6:30 a.m. to 9:30 a.m.; PM data collection at 343 Sansome was from 4:00 p.m. to 6:30 p.m.

Step 3. Allocate Peak-Hour Person-Trips by Mode at each Door
The next step was to allocate the morning or afternoon peak-hour door count trips by mode. The peak-hour trip numbers were calculated from the door counts in Step 1, and the mode shares were estimated from the survey data in Step 2.

Step 4. Calculate Peak-Hour Person-Trips by Mode at the Study Location
Finally, the trips made in and out of each door by each mode were summed to derive morning or afternoon peak-hour person-trips by mode for the overall study location. Note that this method of summing trips by door gives the appropriate weight to doors with different activity levels.

6.1. Example of Analysis Steps at a Study Location

The following example is provided to illustrate how the analysis was conducted at the 180 Grand office building study location at 180 Grand Avenue in Oakland. All 30 sites were analyzed using a similar approach. 180 Grand is a 278,000 gross-square-foot office building with two doors. The West Door serves the street and the designated parking structure across a side street from the building. The South Door serves the street and a shuttle stop. People used both doors when walking to or from the regional transit stop (less than 0.5 miles away) or other activity locations. The steps below were followed for the afternoon peak-hour analysis (parallel steps were followed for the morning peak-hour analysis).

- Step 1. Data collectors counted all people going in and out of both doors to the building on Tuesday, May 8th, 2012. Overall, 318 inbound and outbound trips were counted during the three-hour study period between 4 p.m. and 7 p.m. (251 at the West Door and 67 at the South Door). The peak hour within this three-hour period was between 4:25 p.m. and 5:24 p.m., when 143 inbound and outbound trips were recorded (110 at the West Door and 33 at the South Door).

- Step 2. Surveyors collected information about 65 trips that were made during the three-hour afternoon study period (52 at the West Door and 13 at the South Door). The following text describes how the West Door mode share was calculated. Of the 52 surveyed West Door trips, 22 (42%) were made by men and 30 (58%) were made by women. Compared to the door counts, where 102 (41%) were men and 149 (59%) were women, males were slightly overrepresented among survey respondents. Therefore, when calculating overall mode share, male survey trips were weighted by 0.96 (41%/42%) and female survey trips were weighted by 1.03 (59%/58%). Similarly, of the 52 surveyed West Door trips, 50 (96%) were outbound and two (4%) were inbound. Compared to the door counts, where 213 (85%) were outbound and 38 (15%) were inbound, outbound trips were overrepresented in the survey responses. Therefore, when calculating overall mode share, outbound trips were weighted by 0.88 (85%/96%) and inbound trips were weighted by 3.94 (15%/4%). The overall trip mode share at the West Door was calculated using the average of the gender- and direction-weighted mode shares (Table 6).

Table 6. 180 Grand West Door Mode Share Calculation

	Walk	Auto	Transit	Bicycle	Total
Surveyed Male Trips	0	13	7	2	22
Surveyed Female Trips	2	22	5	1	30
Gender-Weighted Male Trips (0.96)	0	12.49	6.72	1.92	21.13
Gender-Weighted Female Trips (1.03)	2.06	22.64	5.14	1.03	30.87
Gender-Weighted Trips	2.06	35.12	11.87	2.95	52.00
Gender-Weighted Mode Share	**4.0%**	**67.5%**	**22.8%**	**5.7%**	**100.0%**
Surveyed Outbound Trips	1	34	12	3	50
Surveyed Inbound Trips	1	1	0	0	2
Direction-Weighted Outbound Trips (0.88)	0.88	30.01	10.59	2.65	44.13
Direction-Weighted Inbound Trips (3.94)	3.94	3.94	0.00	0.00	7.87
Direction-Weighted Trips	4.82	33.94	10.59	2.65	52.00
Direction-Weighted Mode Share	**9.3%**	**65.3%**	**20.4%**	**5.1%**	**100.0%**
Overall Weighted Mode Share	**6.6%**	**66.4%**	**21.6%**	**5.4%**	**100.0%**

A similar calculation was done for the South Door, providing an overall weighted mode share of 34.4% walk, 17.0% automobile, 42.9% transit, and 5.8% bicycle at the South Door.

- Step 3. The overall weighted mode share for each door was then used to allocate the peak-hour person-trips counted at each door by mode. Of the 110 peak-hour trips passing through the West Door, 7.27 (110*0.066) were walk, 73.05 (110*0.664) were automobile, 23.75 (110*0.216) were transit, and 5.92 (110*0.054) were bicycle. Of the 33 peak-hour trips passing through the South Door, 11.34 (33*0.344) were walk, 5.60 (33*0.170) were automobile, 14.15 (33*0.429) were transit, and 1.91 (33*0.058) were bicycle.

- Step 4. Finally, the peak-hour person-trips by mode at each door were summed to derive the total peak-hour person-trips by mode for the entire site. Of the 143 afternoon peak-hour trips at 180 Grand, 19 (13.0%) were walk, 79 (55.0%) were automobile, 38 (26.5%) were transit, and 8 (5.5%) were bicycle[19].

[19] Note that there are small errors in the final step due to rounding to the nearest number of trips.

7. RESULTS

The door count and intercept survey methodology produced two main sets of results that can inform transportation impact assessment practice in smart-growth areas. The first was the number and share of peak-hour person-trips generated by mode, and the second was a comparison of actual versus ITE peak-hour trips at each study location.

7.1. Peak-Hour Person-Trips by Mode

Survey data were used to determine the distribution of morning peak-hour person-trips by mode at 24 study locations and afternoon peak-hour person-trips by mode at 27 study locations (Table 7). In contrast to standard trip generation assumptions, automobile person-trips accounted for fewer than half of morning peak-hour trips at 10 study locations and fewer than half of afternoon peak-hour trips at 11 study locations. Only three study locations had morning automobile person-trip mode shares greater than 80%, and three study locations had afternoon automobile person-trip mode shares greater than 80%. Person-trips were commonly made by pedestrian and public transit modes at most of the smart-growth study locations. Several study locations also had notable bicycle mode shares (Oakland City Center and Emery Station East).

Table 7. Peak-hour Trips by Mode at Study Locations

					AM Study Period (7 a.m.-10 a.m.)									PM Study Period (4 p.m.-7 p.m.)								
	Targeted Land Uses (ITE Use Code)[1]				Peak Hour									Peak Hour								
Site Name	**Mid- to High-Density Residential**	**Office**	**Commercial Retail Goods**	**Coffee/Donut Shop**	**Estimated Trips[2]**	Estimated Walk Trips	Estimated Auto Trips	Estimated Transit Trips	Estimated Bicycle Trips	% Walk	% Auto	% Transit	% Bicycle	**Estimated Trips[2]**	Estimated Walk Trips	Estimated Auto Trips	Estimated Transit Trips	Estimated Bicycle Trips	% Walk	% Auto	% Transit	% Bicycle
Pegasus	222				**136**	89	42	5	0	65.4%	31.1%	3.4%	0.0%									
Sakura Crossing	223				**106**	18	85	2	1	16.8%	79.9%	2.1%	1.1%	**152**	84	68	0	0	55.6%	44.4%	0.0%	0.0%
Argenta	222				**89**	33	33	17	5	37.5%	37.5%	19.2%	5.8%	**107**	52	29	25	1	48.6%	27.2%	23.1%	1.2%
Fremont Building	223				**50**	17	31	2	0	34.1%	61.6%	4.2%	0.0%	**42**	11	28	1	2	26.0%	67.2%	3.1%	3.6%
Artisan on 2nd	223				**62**	21	41	0	0	33.9%	66.1%	0.0%	0.0%	**51**	10	40	1	1	19.1%	78.1%	1.4%	1.4%
Terraces Apartment Homes[3]	223				**88**	16	69	2	1	18.3%	79.0%	2.1%	0.6%	**85**	37	47	1	0	43.2%	55.6%	1.2%	0.0%
Holly Street Village[4]	223				**175**	23	144	8	0	13.4%	82.2%	4.4%	0.0%	**185**	58	125	1	0	31.5%	67.7%	0.7%	0.0%
Broadway Grand	223				**72**	21	36	16	0	28.9%	49.3%	21.8%	0.0%	**85**	34	34	16	0	40.4%	40.3%	19.3%	0.0%
Archstone at Del Mar Station	223				**98**	17	66	15	0	17.4%	67.0%	15.6%	0.0%	**102**	27	60	8	7	26.0%	58.9%	8.2%	6.8%
The Sierra	223				**121**	20	74	26	1	16.1%	61.2%	21.6%	1.1%	**166**	43	90	32	1	25.8%	54.3%	19.4%	0.5%
Terraces at Emery Station	223				**159**	33	112	15	0	20.6%	70.1%	9.3%	0.0%	**138**	36	98	3	1	26.1%	70.7%	2.4%	0.8%
Victor on Venice	223				**61**	9	51	0	1	15.3%	83.6%	0.0%	1.1%	**76**	4	59	13	0	5.2%	77.6%	17.2%	0.0%
343 Sansome[5]		710			**316**	107	103	82	24	33.8%	32.6%	26.1%	7.5%	**333**	131	84	115	4	39.2%	25.1%	34.6%	1.1%
Convention Plaza		710			**514**	84	214	190	25	16.4%	41.7%	37.0%	4.9%	**491**	78	193	200	21	15.8%	39.3%	40.8%	4.2%
Charles Schwab Building		710			**510**	88	104	309	8	17.2%	20.5%	60.7%	1.7%	**401**	60	76	259	7	14.9%	18.9%	64.5%	1.6%
Park Plaza		710												**53**	9	36	4	4	17.1%	67.8%	7.9%	7.2%
Park Tower		710			**617**	166	383	58	10	26.9%	62.1%	9.5%	1.6%	**566**	107	374	71	15	18.8%	66.1%	12.5%	2.6%
Oakland City Center		710			**248**	4	128	101	15	1.6%	51.8%	40.7%	5.9%	**221**	21	75	112	13	9.6%	34.0%	50.6%	5.9%
180 Grand Avenue		710			**184**	20	96	56	12	10.6%	52.4%	30.6%	6.4%	**143**	19	79	38	8	13.0%	55.0%	26.5%	5.5%
Emery Station East		710			**298**	39	151	67	41	13.0%	50.8%	22.5%	13.7%	**251**	55	140	35	21	22.1%	55.7%	14.1%	8.2%
181 Second Avenue		710			**101**	0	101	0	0	0.0%	100.0%	0.0%	0.0%	**114**	16	94	5	0	13.8%	82.2%	4.0%	0.0%
Oakland City Center			880											**479**	219	0	217	43	45.7%	0.0%	45.4%	8.9%
Paseo Colorado			820											**1551**	279	1208	64	0	18.0%	77.9%	4.1%	0.0%
Fruitvale Station			867											**116**	17	99	0	0	14.4%	85.6%	0.0%	0.0%
343 Sansome[5]				936	**356**	198	41	117	0	55.5%	11.7%	32.9%	0.0%									
Convention Plaza				936	**259**	151	62	47	0	58.2%	23.8%	18.1%	0.0%	**80**	49	25	7	0	60.8%	31.0%	8.2%	0.0%
Park Tower				936	**430**	257	94	79	0	59.9%	21.9%	18.3%	0.0%	**90**	55	23	8	5	60.6%	25.2%	8.9%	5.3%
Oakland City Center[6]				936																		
Broadway Grand				936	**316**	139	141	22	13	44.1%	44.7%	7.1%	4.1%	**237**	148	57	23	9	62.5%	24.1%	9.8%	3.7%
Fruitvale Station				936										**192**	9	179	4	0	4.5%	93.2%	2.2%	0.0%
					5365	1569	2403	1237	156	29.2%	44.8%	23.1%	2.9%	**6508**	1665	3419	1264	159	25.6%	52.5%	19.4%	2.4%

1) ITE Use Codes are from the ITE Trip Generation Manual, Eighth Edition.
2) Surveyed trips includes all reported access and egress trips that occurred during the 3-hour study period window. Note that some AM-period trips were reported by PM respondents and some PM-period trips (e.g., previous evening) were reported by AM respondents. Trips reported by people who did not access the study location were removed.
3) PM data collection at Terraces Apartment Homes was from 3:30 p.m. to 6:30 p.m.
4) PM data collection at Holly Street Village was from 3:30 p.m. to 6:30 p.m.
5) AM data collection at 343 Sansome was from 6:30 a.m. to 9:30 a.m.; PM data collection at 343 Sansome was from 4:00 p.m. to 6:30 p.m.
6) Results were not reported for the Oakland City Center coffee shop because there were fewer than 30 surveys in both the AM and PM study periods.

7.2. Comparison of Actual Peak-Hour Trips to ITE-Estimated Peak-Hour Trips

Actual morning and afternoon peak-hour automobile trips were estimated at all study locations. These actual trips were compared to the number of afternoon peak-hour trips estimated by standard ITE trip generation methods (ITE 2008) (Table 8). Overall, the actual number of vehicle-trips generated during the morning peak hour was lower than standard ITE trip estimates at 19 of the 24 study locations with morning trip data. The weighted average of these 24 study locations shows that ITE morning peak-hour vehicle-trip estimates were 2.3 times higher than actual morning peak-hour vehicle-trips. Actual afternoon peak-hour vehicle-trips were lower than ITE trip estimates at 23 of the 27 study locations. The weighted average of these 27 study locations shows that ITE afternoon peak-hour vehicle-trip estimates were 2.4 times higher than actual afternoon peak-hour vehicle-trips. Note that the difference between actual and ITE-estimated vehicle-trips varied by land use category: there was a larger discrepancy for the office uses (weighted averages showed ITE estimates were 2.9 times higher in the morning and 3.2 times higher in the afternoon) than for the residential uses (ITE estimates were 1.1 times higher in the morning and 1.4 times higher in the afternoon).

Table 8 also shows that the actual total peak-hour person-trip generation was similar to the total peak-hour person-trip generation estimated using the ITE data (incorporating adjustments to reflect vehicle occupancy at study locations) (see far left and far right columns of AM peak-hour and PM peak-hour sections). Weighted averages showed that ITE estimates of total person-trip generation were only 1.1 times higher than actual person-trips in the morning and 1.3 times higher in the afternoon. These findings suggest that overall person-trip generation at the smart-growth study locations was similar to person-trip generation estimated for the sites using ITE Trip Generation data with adjustments; however, larger shares of the trips in smart-growth areas were made by walking, bicycling, and public transit.

Table 8. Actual Peak-hour Vehicle-Trips versus Estimated Vehicle-Trips from Published ITE Rates

	Targeted Land Uses (ITE Use Code)[1]				AM Peak Hour								PM Peak Hour							
Site Name	**Mid- to High-Density Residential**	**Office**	**Commercial Retail Goods**	**Coffee/Donut Shop**	Actual Total Person Trips[2]	Actual Auto Person Trips[3]	Actual Auto Occupancy[4]	**Actual Vehicle Trips**	**ITE-Estimated Vehicle Trips[5]**	Actual-ITE Vehicle Trips	ITE/Actual Vehicle Trips[6]	ITE-Estimated Total Person Trips[7]	Actual Total Person Trips[2]	Actual Auto Person Trips[3]	Actual Auto Occupancy[4]	**Actual Vehicle Trips**	**ITE-Estimated Vehicle Trips[5]**	Actual-ITE Vehicle Trips	ITE/Actual Vehicle Trips[6]	ITE-Estimated Total Person Trips[7]
Pegasus	222				136	42	1.18	**36**	**92**	-56	2.56	109								
Sakura Crossing	223				106	85	1.10	**77**	**66**	11	0.86	73	152	68	1.10	**61**	**86**	-25	1.40	95
Argenta	222				89	33	1.34	**25**	**53**	-28	2.14	71	107	29	1.34	**22**	**62**	-40	2.85	83
Fremont Building	223				50	31	1.23	**25**	**20**	5	0.80	25	42	28	1.23	**23**	**26**	-3	1.13	32
Artisan on 2nd	223				62	41	1.28	**32**	**34**	-2	1.06	44	51	40	1.28	**31**	**44**	-13	1.41	56
Terraces Apartment Homes[8]	223				88	69	1.29	**54**	**78**	-24	1.45	101	85	47	1.29	**37**	**101**	-64	2.76	130
Holly Street Village[9]	223				175	144	1.33	**108**	**107**	1	0.99	142	185	125	1.33	**94**	**139**	-45	1.48	185
Broadway Grand	223				72	36	1.57	**23**	**32**	-9	1.42	50	85	34	1.57	**22**	**42**	-20	1.93	66
Archstone at Del Mar Station	223				98	66	1.31	**50**	**66**	-16	1.32	86	102	60	1.31	**46**	**86**	-40	1.87	113
The Sierra	223				121	74	1.47	**50**	**66**	-16	1.31	97	166	90	1.47	**61**	**86**	-25	1.40	126
Terraces at Emery Station	223				159	112	1.12	**100**	**30**	70	0.30	34	138	98	1.12	**87**	**39**	48	0.45	44
Victor on Venice	223				61	51	1.17	**44**	**33**	11	0.76	39	76	59	1.17	**50**	**43**	7	0.85	50
343 Sansome[10]		710			316	103	1.43	**72**	**355**	-283	4.93	508	333	84	1.43	**58**	**341**	-283	5.83	488
Convention Plaza		710			514	214	1.17	**183**	**481**	-298	2.63	563	491	193	1.17	**165**	**462**	-297	2.80	541
Charles Schwab Building		710			510	104	1.77	**59**	**498**	-439	8.45	881	401	76	1.77	**43**	**479**	-436	11.17	848
Park Plaza		710											53	36	1.27	**28**	**95**	-67	3.36	121
Park Tower		710			617	383	1.20	**319**	**645**	-326	2.02	774	566	374	1.20	**312**	**620**	-308	1.99	744
Oakland City Center		710			248	128	1.28	**100**	**297**	-197	2.96	380	221	75	1.28	**59**	**286**	-227	4.88	366
180 Grand Avenue		710			184	96	1.21	**80**	**271**	-191	3.40	328	143	79	1.21	**65**	**261**	-196	4.02	316
Emery Station East		710			298	151	1.14	**133**	**365**	-232	2.75	416	251	140	1.14	**123**	**351**	-228	2.86	400
181 Second Avenue		710			101	101	1.10	**92**	**77**	15	0.84	85	114	94	1.10	**85**	**74**	11	0.87	81
Oakland City Center			880										479	0	1.28	**0**	**93**	-93	Undefined	119
Paseo Colorado			820										1551	1208	1.57	**770**	**1856**	-1086	2.41	2914
Fruitvale Station			867										116	99	1.50	**66**	**102**	-36	1.54	153
343 Sansome[10]				936	356	41	1.43	**29**	**129**	-100	4.45	184								
Convention Plaza				936	259	62	1.17	**53**	**182**	-129	3.46	213	80	25	1.17	**21**	**63**	-42	2.97	74
Park Tower				936	430	94	1.20	**78**	**194**	-116	2.48	233	90	23	1.20	**19**	**67**	-48	3.55	80
Oakland City Center[11]				936																
Broadway Grand				936	316	141	1.57	**90**	**152**	-62	1.69	239	237	57	1.57	**36**	**53**	-17	1.46	83
Fruitvale Station				936									192	179	1.50	**119**	**54**	65	0.45	81
					5365	2403		**1911**	**4323**	-2412	2.26	5673	6508	3419		**2504**	**6011**	-3507	2.40	8389

1) ITE Use Codes are from the ITE Trip Generation Manual, Eighth Edition.
2) Actual total person trips trips is the total number of person trips during the peak hour at the study location. The estimated number of trips was adjusted for gender bias and different mode shares at each door. Locations with fewer than 30 surveyed trips during a data collection period were not analyzed because they were determined to have insufficient data to estimate mode shares.
3) Actual automobile person trips is the total number of person trips that used an automobile mode at each site.
4) Automobile occupancy was estimated from the total morning or afternoon survey responses at each site.
5) ITE-estimated vehicle trips were calculated using standard Trip Generation Manual (2008) trip rates.
6) The ratio of ITE vehicle trips to actual vehicle trips is undefined when the estimate of actual peak hour vehicle trips was 0.
7) ITE-estimated total person trips were calculated by multiplying the ITE-estimated vehicle trips by the average automobile occupancy for each site. This assumes that the ITE estimates are based sites with 100% automobile mode share.
8) PM data collection at Terraces Apartment Homes was from 3:30 p.m. to 6:30 p.m.
9) PM data collection at Holly Street Village was from 3:30 p.m. to 6:30 p.m.
10) AM data collection at 343 Sansome was from 6:30 a.m. to 9:30 a.m.; PM data collection at 343 Sansome was from 4:00 p.m. to 6:30 p.m.
11) Results were not reported for the Oakland City Center coffee shop because there were fewer than 30 surveys in both the AM and PM study periods.

8. DISCUSSION

The multimodal person-trip data collection methodology has several advantages over existing approaches that use automated technologies to count automobiles entering and exiting access points to developments. These advantages are particularly important in urban areas with mixed-use developments, mixed-use buildings, and a variety of parking arrangements. Advantages include:

- Counting at doors makes it possible to quantify the total number of trips generated by all modes.
- The door counts quantify all people traveling to and from a particular land use, even if the target use is part of a larger, mixed-use building.
- The intercept surveys differentiate between people who are making complete walking trips and people who are walking as a secondary mode to or from parked cars, parked bicycles, and transit stops.

The approach provided multimodal person-trip generation estimates for most of the morning and afternoon study periods. Existing methods that only capture automobile trips would have missed more than half of all person-trips recorded at the California smart-growth study locations (overall, 27% of person-trips were made by walking, 21% by transit, and 3% by bicycle). Practitioners can use multimodal data to inform planning and prioritization of pedestrian, bicycle, and transit facilities near developments in smart-growth areas.

8.1. Comparison of Actual to ITE-Estimated Vehicle-Trips

Comparisons of actual automobile trips with ITE-estimated trips at the study locations show that, as expected, standard ITE methods overestimated the number of vehicle-trips being made to and from study locations in smart-growth areas. It is likely that lower numbers of automobile trips were observed at the study locations because they were in smart-growth areas that have convenient opportunities for walking, bicycling, and taking transit. However, several other factors could affect the comparison of actual and ITE-estimated trips:

- 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. Of the 2,764 recorded automobile trips that used parking, 139 (5%) 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 it increased the actual number of vehicle-trips relative to ITE-estimated vehicle-trips.
- This study also expanded the ITE definition of the morning and afternoon peak-hour periods from two hours to three[20]. Identifying the one-hour period with the highest

[20] Extending the study periods from two hours (7 a.m. to 9 a.m. and 4 p.m. to 6 p.m.) to three hours (7 a.m. to 10 a.m. and 4 p.m. to 7 p.m.) provided a better representation of the actual peaking patterns at the study locations:

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.

- Since 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 these internal trips influenced the overall person-trip generation mode share at these targeted land uses, they did not add vehicle-trips.
- Besides study sites being in smart-growth areas and typical ITE sites being in suburban areas, other contextual differences could also affect the comparison of actual and ITE-estimated vehicle-trips (e.g., region of the country, economic conditions, weather).

8.2. Study Focus

Resources for data collection were limited, so this study focused on several common land use types in the ITE Trip Generation Manual: mid- to high-density residential, office, retail, and coffee/donut shop. It is possible that the data collection methodology described in this report may need to be modified for other types of land uses (e.g., sports stadiums, convention centers, single-family homes). In addition, the differences between ITE and actual trip generation rates identified in this study may not apply to other types of uses in smart-growth areas.

Study locations were in the major urban areas in Northern and Southern California. However, most of the office, retail, and coffee/donut targeted uses were in Northern California. This may have some influence on the results, since the San Francisco and Sacramento regions may have slightly different travel characteristics than the Los Angeles and San Diego regions. Future studies should include more office, retail, and coffee/donut uses from throughout California. Additional applications outside of California could also contribute a wider variety of locations to a national database of multimodal trip generation rates.

The single-day analysis did not capture day-to-day and seasonal variations in travel behavior at the study locations, so the trip generation estimates could be improved by collecting data over a longer time period. Future studies could apply the methodology to a wider range of uses, locations, and time periods.

8.3. Lessons for Future Data Collection

Applying the door count and intercept survey methodology at smart-growth sites in California provided several lessons for applying this approach in the future.

- Hire reliable door counters. These personnel must be motivated, show up on time, and pay attention to detail.
- Train intercept surveyors. During training:

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17 of the 29 morning periods studied had peak hours later than 9 a.m. and 12 of the 30 afternoon periods had peak hours past 6 p.m.

- Demonstrate how to invite people to participate in the survey and ask questions efficiently.
- Clarify that surveyors should not try to guess the mode of transportation people are using if they refuse to participate in the survey. If non-respondents whose mode could be observed "correctly" were included, the modes that could be observed directly would be oversampled, which would introduce bias into the results.
- Make sure surveyors know the type of information to ask for from respondents, even if their questions are worded somewhat differently than the survey form. Intercept survey questions need to be adapted to different site contexts.
- Note the difference between on-site and off-site locations. This is important because trips between different uses on the same site are counted as unique trips, but walking to an on-site parking space is only part of a longer trip.
- Emphasize that an outbound trip is not just the short distance that a person walked from the doorway to the surveyor; it is the whole trip they are making to their next activity location.

- Select study locations with sufficient activity levels or plan for more than three hours of data collection to gather enough survey data to estimate overall mode share. The research team did not obtain the minimum trip sample size during several study periods. Based on this experience, it may be difficult to obtain enough surveyed trips during a three-hour period at residential uses with fewer than 100 units and offices with less than 100,000 gross square feet of leasable space, or retail or restaurant uses that average less than one person exiting every three minutes.
- Consider several approaches to increase survey response rates. It is helpful to ask property managers at residential buildings and offices to provide advance notice to their tenants that the survey will be offered on a specific date. In addition, partial surveys can be offered to capture only the essential trip mode information quickly before respondents walk away.
- Test different orders of survey questions and different types of survey forms. The ideal survey form should be adaptable to full-length or abbreviated surveys and be easy to understand in either case.
- Add a short question to the survey to determine whether or not the person actually accessed the targeted use. This is needed at doorways that may be used by people from other uses in the building or surrounding area besides the targeted use.
- Collect data at doors between the targeted use and parking garage wherever possible. Avoid intercepting drivers (and other people) at driveway entrances to parking garages. This approach worked, but it involved surveying many people who were just using the parking garage for public parking rather than entering the targeted land use. These people were counted and surveyed but needed to be subtracted from the final analysis. It is best to collect data at sites where the property manager grants permission to survey within the parking garage.

9. CONCLUSION

This report focused on how to derive multimodal trip generation rates at study locations in smart-growth areas. It showed that automobile trip generation rates at the smart-growth study locations were lower than standard ITE trip generation rates. In particular, pedestrian, public transit, and bicycle modes are used instead of automobiles for a portion of trips in smart-growth areas. The next phase of the project combined the data collected in spring 2012 with additional trip generation data at smart-growth sites to develop models for adjusting the ITE automobile-trip generation rates to reflect reduced automobile-trip generation in smart-growth areas.

This approach provided the additional benefit of collecting multimodal data that can be used in the future to estimate transit, bicycle, and pedestrian trip generation rates. Multimodal data will need to be collected at many more study locations, especially office and commercial retail sites, in order to have sufficient data to calculate non-automobile trip generation rates for a variety of land uses.

Many communities are encouraging development in urban areas so that they can grow more sustainably and provide more transportation options for residents and visitors. To evaluate transportation impacts of these types of developments more effectively, there is a need to collect new, multimodal trip generation data in smart-growth areas. Future studies can use this approach to gather consistent data that can be compared across study sites in California and throughout the United States.

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DISCLAIMER
The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California. This report does not constitute a standard, specification, or regulation.

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APPENDICES:

A. Study Location Characteristics
B. Standard Door Count Form
C. Standard Intercept Survey Form
D. Instructions for Data Collectors
E. Field Data Quality Checks

APPENDIX A: STUDY LOCATION CHARACTERISTICS

This appendix includes detailed information about all 30 study locations where counts and surveys were collected by the UC Davis research team during spring 2012. Each targeted land use is shown on a separate page, so some multi-use sites have two or three different pages.

The same "site information table" is provided for each study location. It includes the following elements:

- **ITE Land Use Code and classification.** ITE Land Use Codes and classifications are from the ITE Trip Generation Manual, Ninth Edition.
- **Size of targeted land use (or building).** Targeted land use gross square footage (commercial retail or office) or dwelling units (residential) is the size of the whole building for a single-use building, or the size of an individual targeted land use within a multi-use building. This measurement includes walls, floors, staircases, elevators, and other areas within the building that may not be used for the primary activity at the site (e.g., this measure represents "gross square feet").
- **Proportion occupied.** Proportion (0.00 to 1.00) of the targeted land use gross square footage (commercial retail or office) or dwelling units (residential) that are occupied.
- **Residential population within a 0.5-mile, straight-line radius.** Number of residents within a 0.5-mile, straight-line radius of the center of the study site. This measure was calculated in GIS using US Census block group data (2010), but it is also possible to estimate the population within 0.5-miles from online sources[21].

[21] The population and employment measures 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 for practitioners. 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.

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,

- **Jobs within a 0.5-mile, straight-line radius.** Number of jobs within a 0.5-mile, straight-line radius of the center of the study site. This measure was calculated in GIS using U.S. Census block group data (2010), but it is also possible to estimate the population within 0.5-miles from online sources[21].
- **Straight-line distance to center of central business district (CBD).** Straight-line distance from center of study site to center of the Los Angeles, Oakland, Sacramento, or San Francisco CBD (in miles).
- **Average building setback distance from each door to nearest sidewalk.** Average straight-line distance to the nearest sidewalk from all major building entrances (in feet). Major entrances include the main pedestrian entrance and automobile garage entrances.
- **Metered on-street parking within a 0.1-mile, straight-line radius.** Presence of metered parking within a 0.1-mile, straight-line radius of the center of the study site. Metered parking only includes metered on-street parking. It does not include off-street surface lots or parking structures.
- **PM peak-hour bus line stops within a 0.25-mile, straight-line radius[22].** 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.
- **PM peak-hour passenger train line stops within a 0.5-mile, straight-line radius[22].** Number of individual rail stop locations on all passenger 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.

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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 estimate population within the buffer area using whole census block groups (Missouri Census Data Center) or census blocks (Longitudinal Household-Employment Dynamics). They do not allocate the proportion of the census block group that is within the buffer area. For census block groups that straddle the buffer line, they simply add the total population of the census block group if more than half of the block group is within the buffer line or add zero population if less than half of the block group is within the buffer line. This creates less accurate estimates than were used for model development, especially in areas that have larger-area census block groups (i.e., more suburban areas). However, the estimated population and employment numbers should be sufficient for planning-level analysis.

[22] 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.

- **Proportion of site area covered by surface parking lots.** Proportion (0.00 to 1.00) of site surface area covered by surface parking. Parking on top of a building or in parking structures is not counted as surface parking.

The "peak hour person-trip generation" table shows the actual (i.e., collected through counts and surveys) number of automobile[23], pedestrian[24], public transit[25], and bicycle[26] trips made to and from the study location during the AM and PM peak hours on the day of data collection. Pie charts provide a graphic representation of actual person trip mode share during each peak hour.

The "peak hour vehicle-trip generation" table includes actual (i.e., collected through counts and surveys) vehicle trip data during the AM and PM peak hours on the day of data collection and vehicle-trip[27] estimates based on ITE trip generation rates. The first row of the "actual (collected)" column shows the vehicle occupancy reported by survey respondents who used automobiles, and the second row shows the actual number of vehicle trips counted at the study location during the AM and PM peak hours on the day of data collection (vehicle trips = automobile person trips/reported vehicle occupancy). The third row of the "actual" column is the trip rate (per 1000 gross square feet for commercial retail or office land uses; per dwelling unit for residential uses). The second and third rows of the table include ITE-estimated vehicle trips and trip rates (on the right side) for comparison with the actual data.

Graphs at the bottom of each page illustrate the person-trip generation peaking patterns and identify the specific peak hour during the AM and PM study periods at each study location.

[23] Automobile person-trips include trips made by people in cars, trucks, vans, taxis, vanpools, paratransit, motorcycles, and motorized delivery vehicles. They do not include trips made by people in public transit vehicles or trips made by people on bicycles.

[24] Pedestrian person-trips include trips made by people on foot or using any type of assistive device (e.g., wheelchair, walker). The 2009 Manual on Uniform Traffic Control Devices (MUTCD) defines a pedestrian as "a person on foot, in a wheelchair, on skates, or on a skateboard."

[25] Public transit person-trips include trips made by people using any of the following modes (as defined by the American Public Transit Association, http://www.apta.com/resources/statistics/Pages/glossary.aspx): bus, heavy rail (metro, subway, rapid transit), light rail (streetcar, tramway, trolley), commuter rail (regional rail), monorail, ferry boat, trolleybus, cable car, automated guideway transit (personal rapid transit), aerial tramway, and inclined plane. The following modes are not classified as public transit: taxi, paratransit, and vanpool (including airport shuttles).

[26] Bicycle person-trips include trips made by people traveling on two-wheeled vehicles except motorcycles, mopeds and motorized scooters. People riding electric bicycles (i.e., bicycles with electric power assistance) are typically (and legally) classified as bicyclists. The 2009 MUTCD defines a bicycle as "a pedal-powered vehicle upon which the human operator sits."

[27] Vehicle-trips, as defined by ITE, include trips made by motorized vehicles, regardless of occupancy (i.e., a car with two people counts as two automobile person-trips but only counts as one vehicle trip). The ITE definition of vehicle-trips also includes trips made by public transit vehicles across a site boundary (one bus counts as one vehicle-trip, regardless of occupancy). However, since there were no on-site transit stops at the study locations, the vehicle-trips in this study do not include any trips by public transit vehicles. Vehicle-trips do not include trips made on bicycles, even though bicycles are classified as vehicles by the California Vehicle Code.

STUDY LOCATION 1.1: 343 SANSOME (OFFICE)
Address: 343 Sansome Street
City: San Francisco, CA
Data Collection Date: Thursday, March 29, 2012

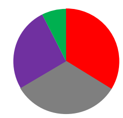
Brief Description: This 16-story office building is located in the heart of the San Francisco Financial District. It has two street-level entrances and an internal connection to a ground-floor coffee shop (with its own street-level entrance). There is also a two-level parking garage below the building, and each level has direct access to the offices. Public parking is available in the garage.

Site Information

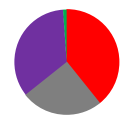
ITE Land Use Code and classification	710 (General Office)
Size of targeted land use (or building)	256,985 GSF
Proportion occupied (0.00 to 1.00)	0.89
Residential population within a 0.5-mile, straight-line radius	18,491
Jobs within a 0.5-mile, straight-line radius	136,400
Straight-line distance to center of central business district (CBD)	0.4 miles (San Francisco)
Average building setback distance from each door to closest sidewalk	5 feet
Metered on-street parking within a 0.1-mile, straight-line radius	Yes
PM peak-hour bus line stops within a 0.25-mile, straight-line radius	143
PM peak-hour passenger train line stops within a 0.5-mile, straight-line radius	59
Proportion of site area covered by surface parking lots (0.00 to 1.00)	0.00

Peak-Hour Person-Trip Generation

	Actual (Collected)	
	AM	PM
Automobile	103	84
Pedestrian	107	131
Public Transit	82	115
Bicycle	24	4
Total	**316**	**333**



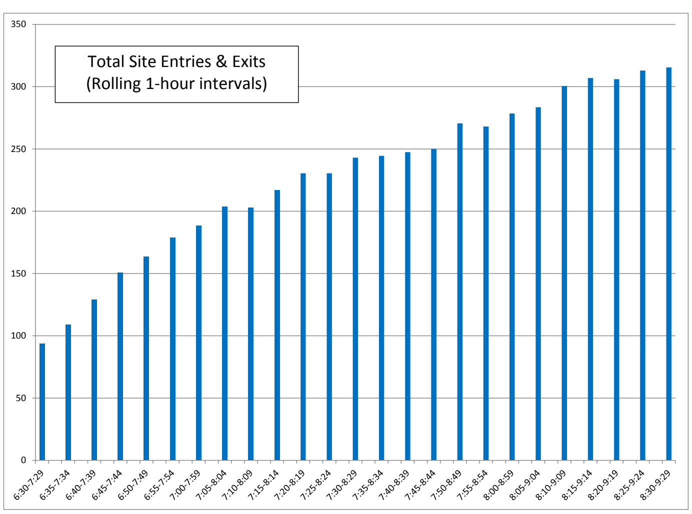
AM



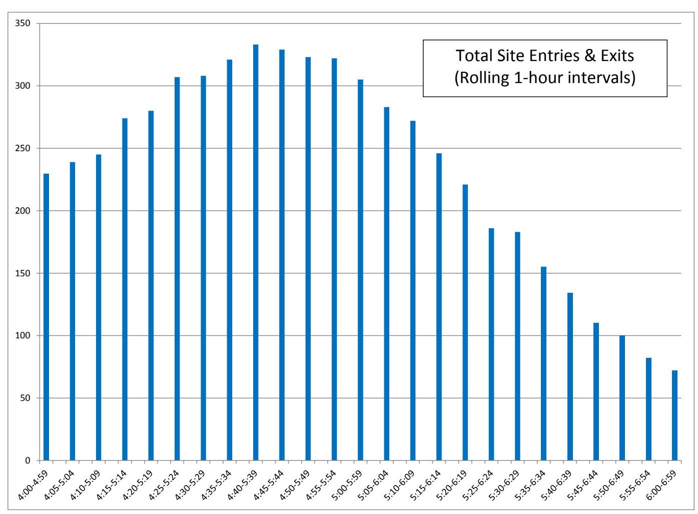
PM

Peak-Hour Vehicle-Trip Generation

	Actual (Collected)		ITE-Estimated	
	AM	PM	AM	PM
Reported Vehicle Occupancy	1.43	1.43	N/A	N/A
Vehicle-Trips	72	58	355	341
Trip Rate (/1000 GSF)	**0.315**	**0.256**	**1.55**	**1.49**



AM Peak Hour: 8:30-9:29 a.m.



PM Peak Hour: 4:40-5:39 p.m.

STUDY LOCATION 1.2: 343 SANSOME (COFFEE/DONUT SHOP)
Address: 343 Sansome Street
City: San Francisco, CA
Data Collection Date: Thursday, March 29, 2012

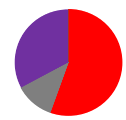
Brief Description: This coffee shop is located on the ground floor of a 16-story office building in the heart of the San Francisco Financial District. The coffee shop has its own street-level entrance and an internal connection to the lobby of the office building. There is a two-level parking garage below the building. Public parking is available in the garage.

Site Information

ITE Land Use Code and classification	936 (Coffee/Donut Shop)
Size of targeted land use (or building)	1,097 GSF
Proportion occupied (0.00 to 1.00)	N/A
Residential population within a 0.5-mile, straight-line radius	18,491
Jobs within a 0.5-mile, straight-line radius	136,400
Straight-line distance to center of central business district (CBD)	0.4 miles (San Francisco)
Average building setback distance from each door to closest sidewalk	0 feet
Metered on-street parking within a 0.1-mile, straight-line radius	Yes
PM peak-hour bus line stops within a 0.25-mile, straight-line radius	143
PM peak-hour passenger train line stops within a 0.5-mile, straight-line radius	59
Proportion of site area covered by surface parking lots (0.00 to 1.00)	0.00

Peak-Hour Person-Trip Generation

	Actual (Collected)	
	AM	PM
Automobile	41	
Walk	198	
Public Transit	117	
Bicycle	0	
Total	**356**	

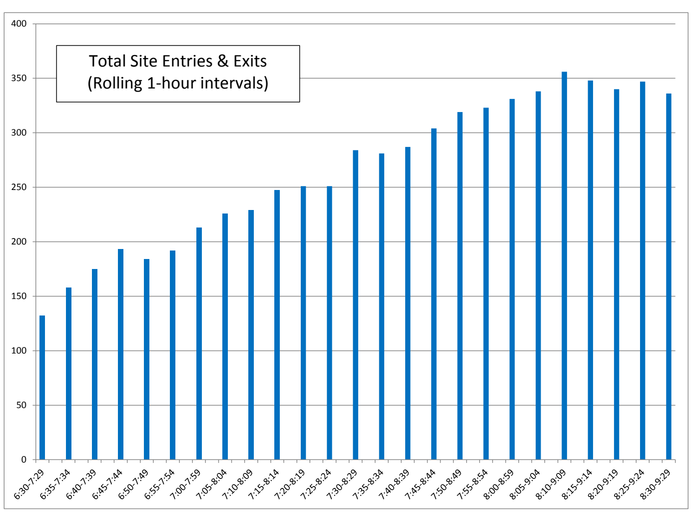


AM

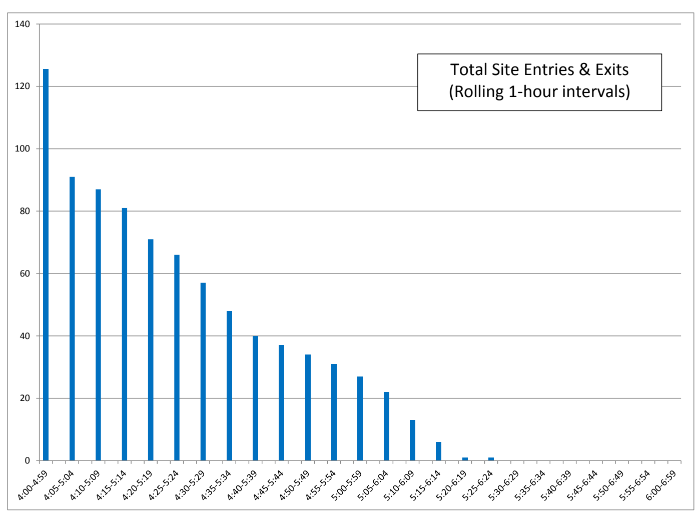
N/A **PM**

Peak-Hour Vehicle-Trip Generation

	Actual (Collected)		ITE-Estimated	
	AM	PM	AM	PM
Vehicle Occupancy	1.43		N/A	
Vehicle-Trips	29		129	
Trip Rate (/1000 GSF)	**26.4**		**117**	



AM Peak Hour: 8:10-9:09 a.m.



PM Peak Hour: 4:00-4:59 p.m.

STUDY LOCATION 2.1: OAKLAND CITY CENTER (OFFICE)
Address: 1333 Broadway
City: Oakland, CA
Data Collection Date: Tuesday, April 24, 2012

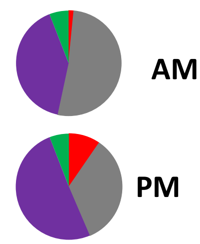
Brief Description: This 10-story office building is located in Downtown Oakland near one of the entrances to the 12th Street, Oakland City Center BART station. It has two street-level entrances. There is a high-frequency AC Transit Rapid bus stop outside the east entrance. The Oakland City Center development parking garage serves the office building, but there is no direct connection between this garage and the building.

Site Information

ITE Land Use Code and classification	710 (General Office)
Size of targeted land use (or building)	239,821 GSF
Proportion occupied (0.00 to 1.00)	0.80
Residential population within a 0.5-mile, straight-line radius	14,057
Jobs within a 0.5-mile, straight-line radius	46,443
Straight-line distance to center of central business district (CBD)	0.03 miles (Oakland)
Average building setback distance from each door to closest sidewalk	0 feet
Metered on-street parking within a 0.1-mile, straight-line radius	Yes
PM peak-hour bus line stops within a 0.25-mile, straight-line radius	137
PM peak-hour passenger train line stops within a 0.5-mile, straight-line radius	6
Proportion of site area covered by surface parking lots (0.00 to 1.00)	0.00

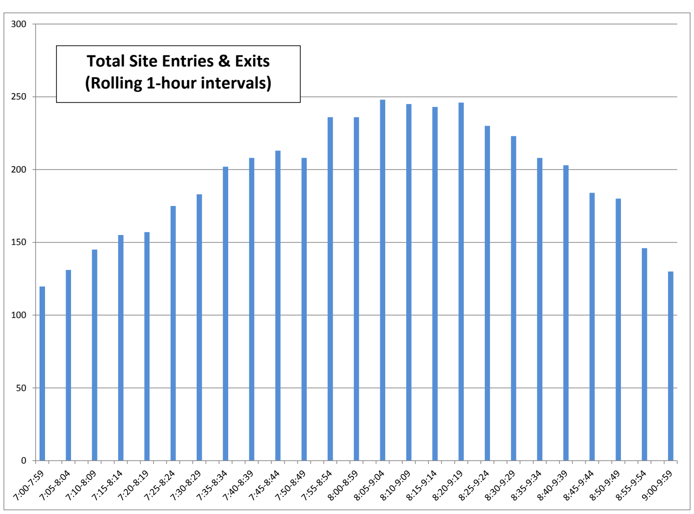
Peak-Hour Person-Trip Generation

	Actual (Collected)	
	AM	PM
Automobile	128	75
Pedestrian	4	21
Public Transit	101	112
Bicycle	15	13
Total	**248**	**221**

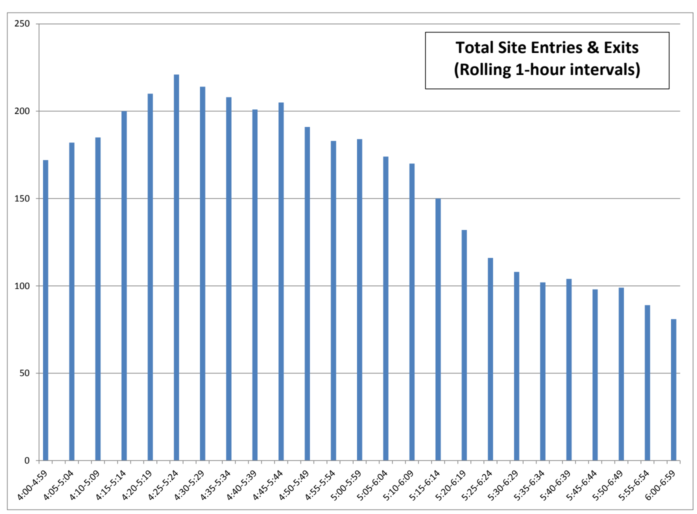


Peak-Hour Vehicle-Trip Generation

	Actual (Collected)		ITE-Estimated	
	AM	PM	AM	PM
Reported Vehicle Occupancy	1.28	1.28	N/A	N/A
Vehicle-Trips	100	59	297	286
Trip Rate (/1000 GSF)	**0.523**	**0.306**	**1.55**	**1.49**

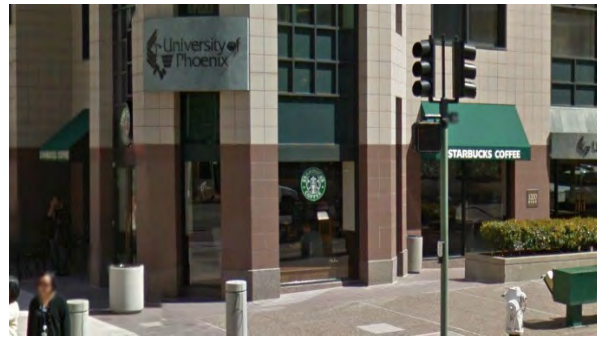


AM Peak Hour: 8:05-9:04 a.m.



PM Peak Hour: 4:25-5:24 p.m.

STUDY LOCATION 2.2: OAKLAND CITY CENTER (COFFEE/DONUT SHOP)
Address: 1333 Broadway
City: Oakland, CA
Data Collection Date: Tuesday, April 24, 2012



Source: Google Maps

Brief Description: This coffee shop is located on the ground floor of a three-story office building and is part of the Oakland City Center Development. Located only 0.3 miles from the 12th Street Bart Station, the coffee shop is in the heart of the Oakland Central Business District. It is near large office buildings and other small, ground-level restaurants and retail stores. The coffee shop has one street-level entry that is served by the Oakland City Center pedestrian plaza (13th Street), Clay Street sidewalks, and a signalized crosswalk directly adjacent to the store across Clay Street. Metered on-street parking is available on Clay Street, and off-street parking is available in the Oakland City Center public parking garage.

Site Information

ITE Land Use Code and classification	936 (Coffee/Donut Shop)
Size of targeted land use (or building)	1,100 GSF
Proportion occupied (0.00 to 1.00)	N/A
Residential population within a 0.5-mile, straight-line radius	14,057
Jobs within a 0.5-mile, straight-line radius	46,443
Straight-line distance to center of central business district (CBD)	0.03 miles (Oakland)
Average building setback distance from each door to closest sidewalk	0 feet
Metered on-street parking within a 0.1-mile, straight-line radius	Yes
PM peak-hour bus line stops within a 0.25-mile, straight-line radius	137
PM peak-hour passenger train line stops within a 0.5-mile, straight-line radius	6
Proportion of site area covered by surface parking lots (0.00 to 1.00)	0.00

Peak-Hour Person-Trip Generation

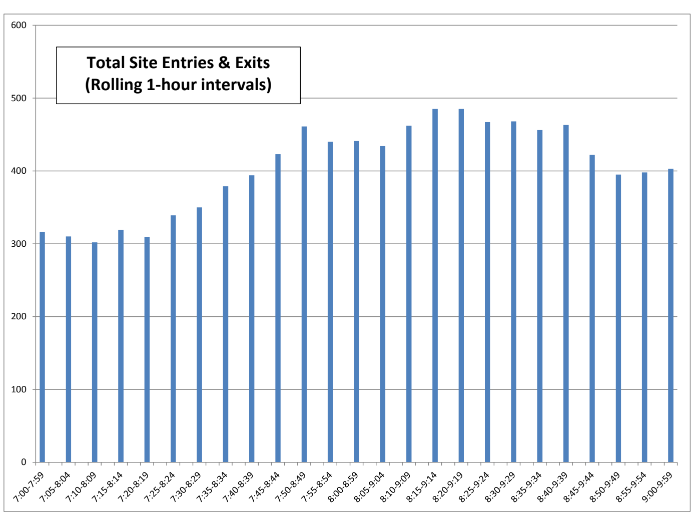
	Actual (Collected)	
	AM	PM
Automobile		
Walk		
Public Transit		
Bicycle		
Total		

N/A **AM**

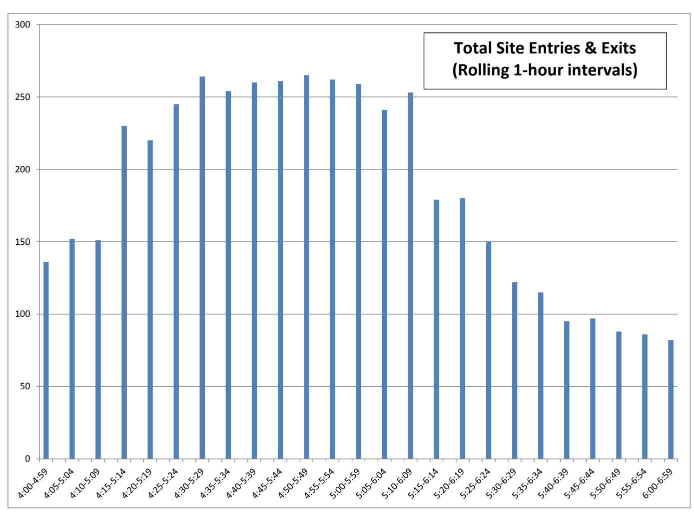
N/A **PM**

Peak-Hour Vehicle-Trip Generation

	Actual (Collected)		ITE-Estimated	
	AM	PM	AM	PM
Reported Vehicle Occupancy	N/A	N/A	N/A	N/A
Vehicle-Trips	N/A	N/A	129	45
Trip Rate (/1000 GSF)	**N/A**	**N/A**	**117**	**40.8**



AM Peak Hour: 8:20-9:19 a.m.



PM Peak Hour: 4:50-5:49 p.m.

STUDY LOCATION 2.3: OAKLAND CITY CENTER (RETAIL)
Address: 1333 Broadway
City: Oakland, CA
Data Collection Date: Tuesday, April 24, 2012

Source: Google Maps

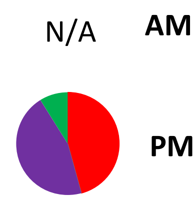
Brief Description: This retail business is located on the ground floor of the office building described as Study Location 2.1. The single entrance is on Broadway, which is the main commercial street in Downtown Oakland. The store doorway is within 0.1 mile of an entrance to the 12th Street Bart Station, and a high-frequency AC Transit Rapid bus stop. There is no off-street parking designated for the store; customers may use the Oakland City Center public parking garage or metered on-street spaces on nearby streets. However, the public parking garage does not connect directly to the store, and the streets immediately adjacent to the store do not have on-street parking.

Site Information

ITE Land Use Code and classification	880 (Commercial Retail Goods)
Size of targeted land use (or building)	11,000 GSF
Proportion occupied (0.00 to 1.00)	N/A
Residential population within a 0.5-mile, straight-line radius	14,057
Jobs within a 0.5-mile, straight-line radius	46,443
Straight-line distance to center of central business district (CBD)	0.03 miles (Oakland)
Average building setback distance from each door to closest sidewalk	0 feet
Metered on-street parking within a 0.1-mile, straight-line radius	Yes
PM peak-hour bus line stops within a 0.25-mile, straight-line radius	137
PM peak-hour passenger train line stops within a 0.5-mile, straight-line radius	6
Proportion of site area covered by surface parking lots (0.00 to 1.00)	0.00

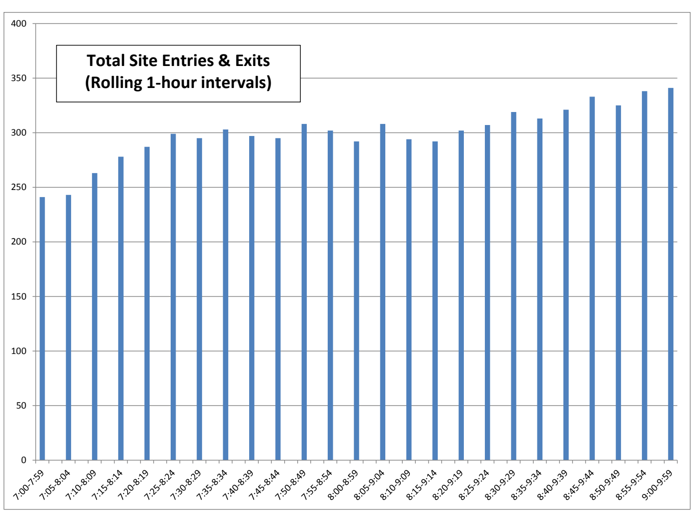
Peak-Hour Person-Trip Generation

	Actual (Collected)	
	AM	PM
Automobile		0
Walk		219
Public Transit		217
Bicycle		43
Total		**479**

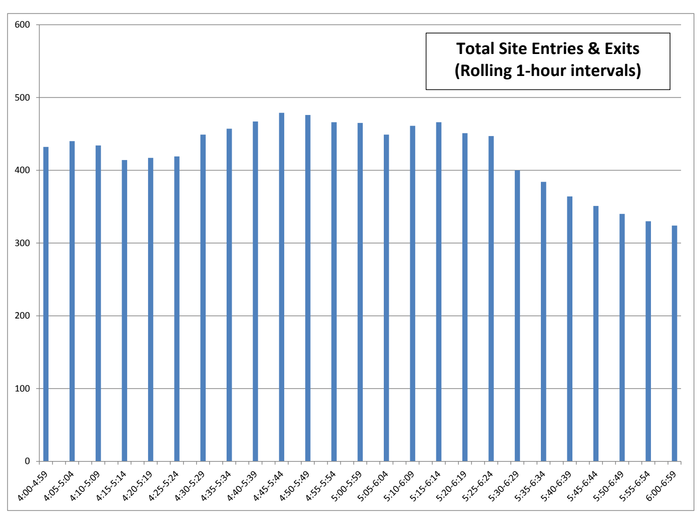


Peak-Hour Vehicle-Trip Generation

	Actual (Collected)		ITE-Estimated	
	AM	PM	AM	PM
Reported Vehicle Occupancy	N/A	1.28	N/A	N/A
Vehicle-Trips	N/A	0	35	93
Trip Rate (/1000 GSF)	**N/A**	**0.000**	**3.20**	**8.42**



AM Peak Hour: 9:00-9:59 a.m.



PM Peak Hour: 4:45-5:44 p.m.

STUDY LOCATION 3.1: FRUITVALE STATION (RETAIL)

Address: 3100 E. 9th Street
City: Oakland, CA
Data Collection Date: Thursday, April 26, 2012

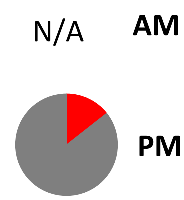
Brief Description: This commercial store is located on the northeast side of the Fruitvale Station shopping center. The store has a single entrance. The shopping center contains more than 10 one-story retail stores, and these stores are served by a free, shared parking lot with more than 200 spaces. The shopping center is oriented to provide easy access to a nearby Interstate 880 interchange. The Fruitvale BART Station is just under 0.5 miles away, but there are no special pedestrian connections between the shopping center and the transit station. To access BART, customers must cross Fruitvale Avenue, a four-lane, major arterial roadway in East Oakland.

Site Information

ITE Land Use Code and classification	867 (Commercial Retail Goods)
Size of targeted land use (or building)	30,037 GSF
Proportion occupied (0.00 to 1.00)	N/A
Residential population within a 0.5-mile, straight-line radius	6,617
Jobs within a 0.5-mile, straight-line radius	3,785
Straight-line distance to center of central business district (CBD)	3.14 miles (Oakland)
Average building setback distance from each door to closest sidewalk	208 feet
Metered on-street parking within a 0.1-mile, straight-line radius	No
PM peak-hour bus line stops within a 0.25-mile, straight-line radius	23
PM peak-hour passenger train line stops within a 0.5-mile, straight-line radius	3
Proportion of site area covered by surface parking lots (0.00 to 1.00)	0.50

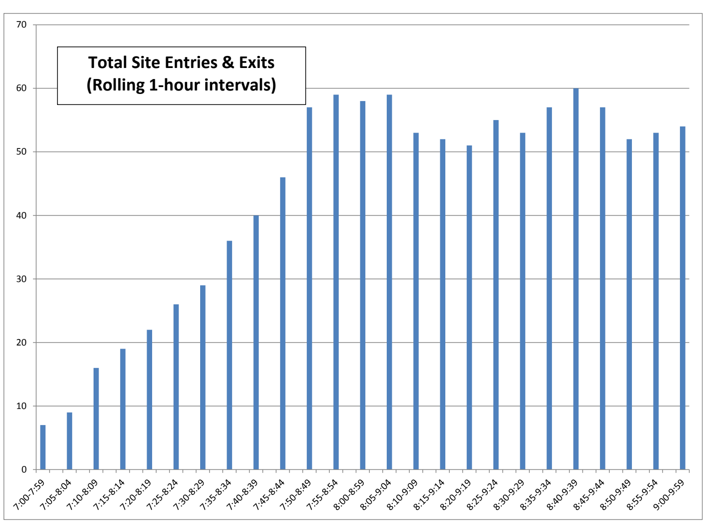
Peak-Hour Person-Trip Generation

	Actual (Collected)	
	AM	PM
Automobile		99
Walk		17
Public Transit		0
Bicycle		0
Total		**116**

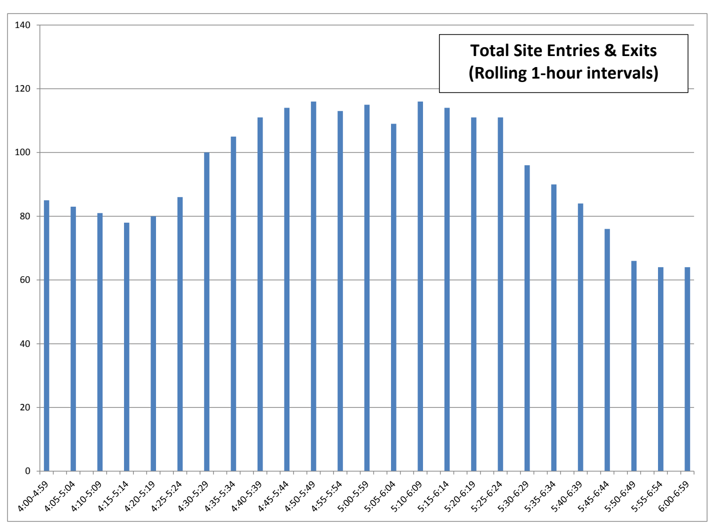


Peak-Hour Vehicle-Trip Generation

	Actual (Collected)		ITE-Estimated	
	AM	PM	AM	PM
Reported Vehicle Occupancy	1.50	1.50	N/A	N/A
Vehicle-Trips	N/A	66	N/A	102
Trip Rate (/1000 GSF)	**N/A**	**2.20**	**N/A**	**3.40**



AM Peak Hour: 8:40-9:39 a.m.



PM Peak Hour: 4:50-5:49 p.m.

STUDY LOCATION 3.2: FRUITVALE STATION (COFFEE/DONUT SHOP)
Address: 3100 E. 9th Street
City: Oakland, CA
Data Collection Date: Thursday, April 26, 2012

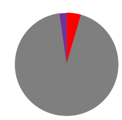
Brief Description: The coffee shop is located on the southwest side of the Fruitvale Station shopping center adjacent to other commercial businesses. It has one entrance and does not have a drive thru. The shopping center contains more than 10 one-story retail stores, and these stores are served by a free, shared parking lot with more than 200 spaces. The shopping center is oriented to provide easy access to a nearby Interstate 880 interchange. The Fruitvale BART Station is just under 0.5 miles away, but there are no special pedestrian connections between the shopping center and the transit station. To access BART, customers must cross Fruitvale Avenue, a four-lane, major arterial roadway in East Oakland.

Site Information

ITE Land Use Code and classification	936 (Coffee/Donut Shop)
Size of targeted land use (or building)	1,329 GSF
Proportion occupied (0.00 to 1.00)	N/A
Residential population within a 0.5-mile, straight-line radius	6,617
Jobs within a 0.5-mile, straight-line radius	3,785
Straight-line distance to center of central business district (CBD)	3.14 miles (Oakland)
Average building setback distance from each door to closest sidewalk	79 feet
Metered on-street parking within a 0.1-mile, straight-line radius	No
PM peak-hour bus line stops within a 0.25-mile, straight-line radius	23
PM peak-hour passenger train line stops within a 0.5-mile, straight-line radius	3
Proportion of site area covered by surface parking lots (0.00 to 1.00)	0.50

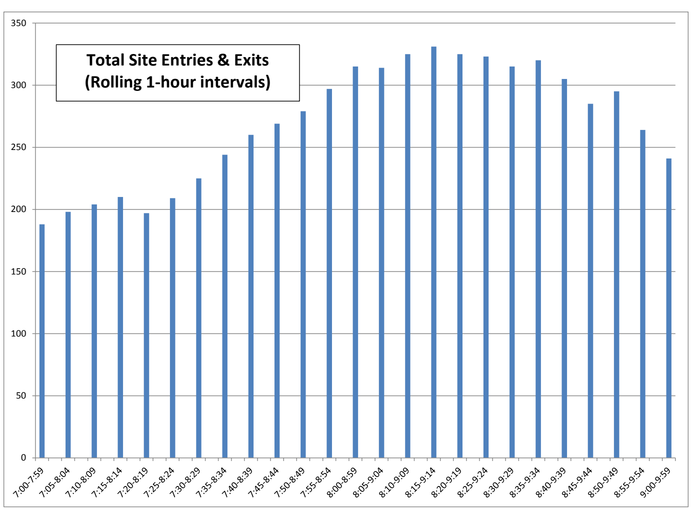
Peak-Hour Person-Trip Generation

	Actual (Collected)	
	AM	PM
Automobile		179
Walk		9
Public Transit		4
Bicycle		0
Total		**192**

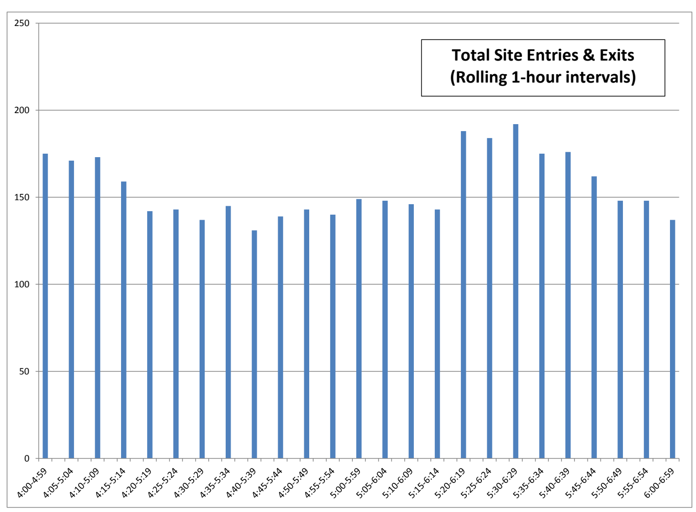


Peak-Hour Vehicle-Trip Generation

	Actual (Collected)		ITE-Estimated	
	AM	PM	AM	PM
Reported Vehicle Occupancy	1.50	1.50	N/A	N/A
Vehicle-Trips	N/A	119	156	54
Trip Rate (/1000 GSF)	**N/A**	**89.8**	**117**	**40.8**



AM Peak Hour: 8:15-9:14 a.m.



PM Peak Hour: 5:30-6:29 p.m.

STUDY LOCATION 4.1: SAKURA CROSSING (RESIDENTIAL)
Address: 235 S. San Pedro Street
City: Los Angeles, CA
Data Collection Date: Tuesday, May 1, 2012

Photos by Texas A&M Transportation Institute

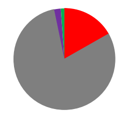
Brief Description: Sakura Crossing is a six-story, modern rental apartment building located on the southeastern edge of Downtown Los Angeles (Little Tokyo neighborhood). Adjacent blocks to the north, east and west have been at least partly redeveloped with residential and retail uses during the past few decades. Adjacent sidewalks are wide and in good condition. There are bus stops nearby, and the Little Tokyo/Arts District Orange line Metrorail station is about 0.25 miles away. Parking for apartment residents is in an underground facility that is accessible from the east side of the site. The also building contains a ground floor bar and restaurant accessible only from the street but these were not included in the study.

Site Information

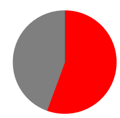
ITE Land Use Code and classification	223 (Mid- to High- Density Residential)
Size of targeted land use (or building)	230 units
Proportion occupied (0.00 to 1.00)	.96
Residential population within a 0.5-mile, straight-line radius	13,310
Jobs within a 0.5-mile, straight-line radius	65,969
Straight-line distance to center of central business district (CBD)	0.76 miles (Los Angeles)
Average building setback distance from each door to closest sidewalk	13 feet
Metered on-street parking within a 0.1-mile, straight-line radius	Yes
PM peak-hour bus line stops within a 0.25-mile, straight-line radius	24
PM peak-hour passenger train line stops within a 0.5-mile, straight-line radius	1
Proportion of site area covered by surface parking lots (0.00 to 1.00)	0.00

Peak-Hour Person-Trip Generation

	Actual (Collected)	
	AM	PM
Automobile	85	68
Walk	18	84
Public Transit	2	0
Bicycle	1	0
Total	**106**	**152**



AM

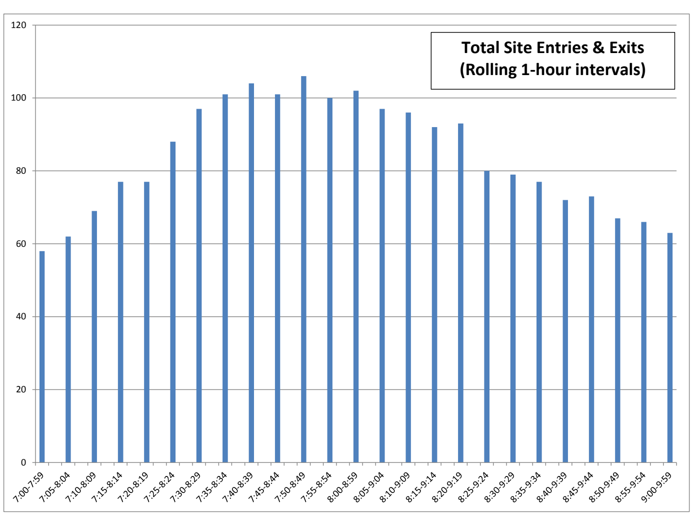


PM

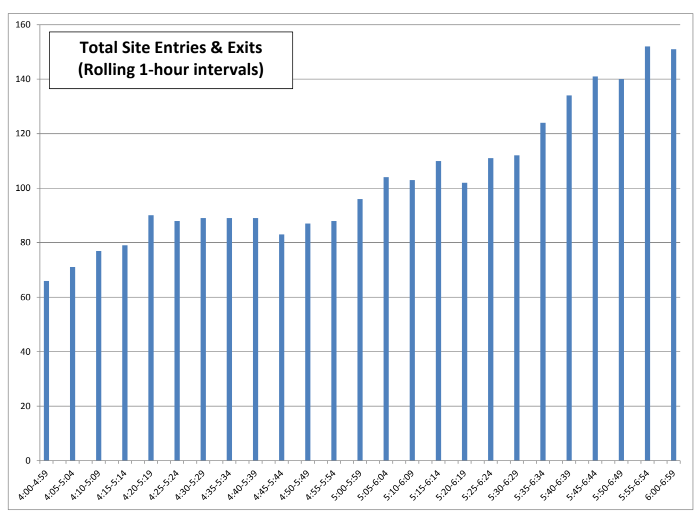
Peak-Hour Vehicle-Trip Generation

	Actual (Collected)		ITE-Estimated	
	AM	PM	AM	PM
Reported Vehicle Occupancy*	1.10	1.10	N/A	N/A
Vehicle-Trips	77	61	66	86
Trip Rate (/1000 GSF)	**0.35**	**0.28**	**0.30**	**0.39**

*Vehicle occupancy from direct observations at this site was 1.12 in the AM period and 1.17 in the PM period.



AM Peak Hour: 7:50-8:49 a.m.



PM Peak Hour: 5:55-6:54 p.m.

STUDY LOCATION 5.1: ARTISAN ON 2ND (RESIDENTIAL)
Address: 601 E. Second Street
City: Los Angeles, CA
Data Collection Date: Tuesday, May 1, 2012


Photo by Texas A&M Transportation Institute

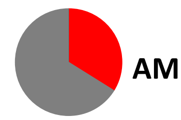
Brief Description: Artisan on 2nd is a modern, four-story rental apartment development located just outside the southeastern corner of Downtown Los Angeles (Little Tokyo neighborhood). It is one of two rental apartment developments on the block that have resulted from recent redevelopment in and adjacent to southeastern downtown L.A. The blocks to the west and south are fully occupied by other rental apartment complexes. Most other nearby blocks are occupied by older industrial development or surface parking lots. The Little Tokyo/Arts District Station on the Metrorail Orange Line is only 2.5 blocks away. Artisan is served by a gated parking garage, accessible by a single access point. On-street parking is also available on adjacent streets.

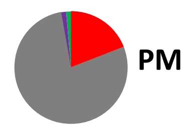
Site Information

ITE Land Use Code and classification	223 (Mid- to High- Density Residential)
Size of targeted land use (or building)	118 units
Proportion occupied (0.00 to 1.00)	.96
Residential population within a 0.5-mile, straight-line radius	7,065
Jobs within a 0.5-mile, straight-line radius	26,978
Straight-line distance to center of central business district (CBD)	1.07 miles (Los Angeles)
Average building setback distance from each door to closest sidewalk	28 feet
Metered on-street parking within a 0.1-mile, straight-line radius	Yes
PM peak-hour bus line stops within a 0.25-mile, straight-line radius	9
PM peak-hour passenger train line stops within a 0.5-mile, straight-line radius	1
Proportion of site area covered by surface parking lots (0.00 to 1.00)	0.15

Peak-Hour Person-Trip Generation

	Actual (Collected)	
	AM	PM
Automobile	41	40
Walk	21	10
Public Transit	0	1
Bicycle	0	1
Total	**62**	**52**

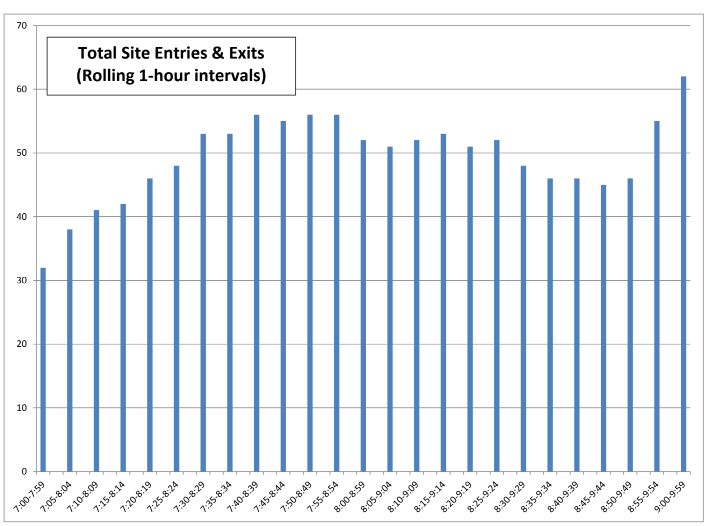




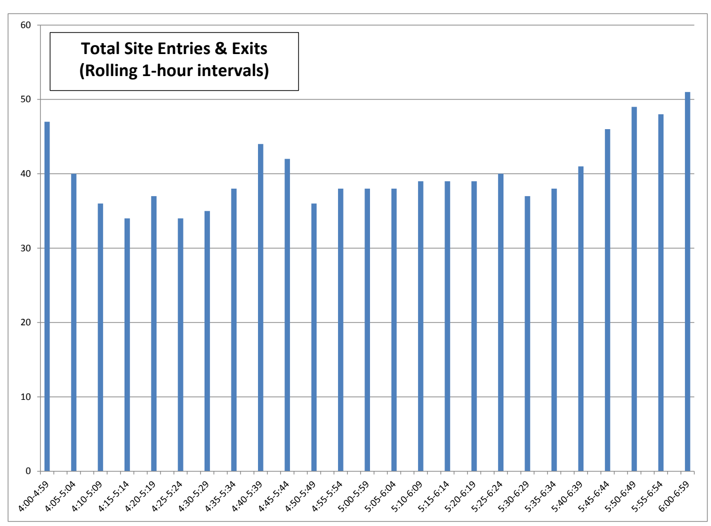
Peak-Hour Vehicle-Trip Generation

	Actual (Collected)		ITE-Estimated	
	AM	PM	AM	PM
Reported Vehicle Occupancy*	1.28	1.28	N/A	N/A
Vehicle-Trips	32	31	34	44
Trip Rate (/1000 GSF)	**0.28**	**0.27**	**0.30**	**0.39**

*Vehicle occupancy from direct observations at this site was 1.14 in the AM period and 1.20 in the PM period.



AM Peak Hour: 9:00-9:59 a.m.



PM Peak Hour: 6:00-6:59 p.m.

STUDY LOCATION 6.1: VICTOR ON VENICE (RESIDENTIAL)
Address: 10001 Venice Boulevard
City: Los Angeles, CA
Data Collection Date: Wednesday, May 2, 2012

Photo by Texas A&M Transportation Institute

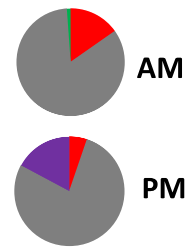
Brief Description: The Victor on Venice is a recently-developed rental apartment building located along the high volume Venice Boulevard corridor. The building is fairly compact with very short setbacks between the sidewalk and the building. It has an interior courtyard. Parking access to the underground garage is one-way from Clarington Avenue on the west and exits to Dunn Drive on the east. Express and local bus service is available along Venice Boulevard. A future Metrorail extension will serve the area near Victor on Venice but will not open for some time. The planned Culver City station will be about 0.7 miles east of the apartments.

Site Information

ITE Land Use Code and classification	223 (Mid- to High- Density Residential)
Size of targeted land use (or building)	116 units
Proportion occupied (0.00 to 1.00)	.95
Residential population within a 0.5-mile, straight-line radius	15,811
Jobs within a 0.5-mile, straight-line radius	5,267
Straight-line distance to center of central business district (CBD)	8.50 miles (Los Angeles)
Average building setback distance from each door to closest sidewalk	0 feet
Metered on-street parking within a 0.1-mile, straight-line radius	Yes
PM peak-hour bus line stops within a 0.25-mile, straight-line radius	18
PM peak-hour passenger train line stops within a 0.5-mile, straight-line radius	0
Proportion of site area covered by surface parking lots (0.00 to 1.00)	0.00

Peak-Hour Person-Trip Generation

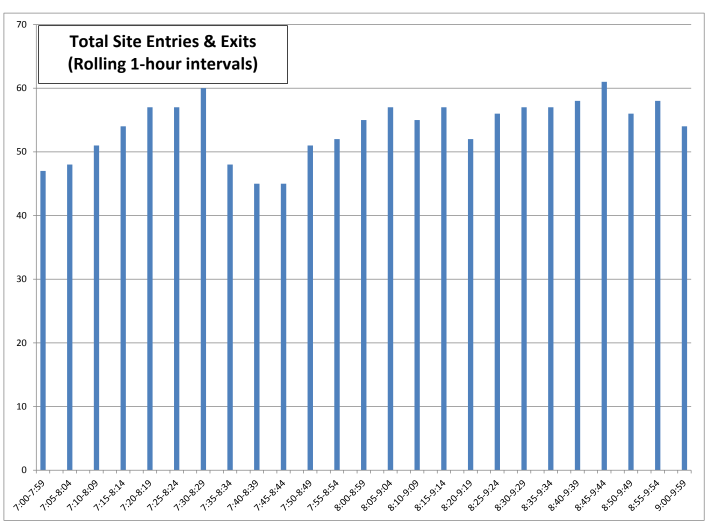
	Actual (Collected)	
	AM	PM
Automobile	51	59
Walk	9	4
Public Transit	0	13
Bicycle	1	0
Total	**61**	**76**



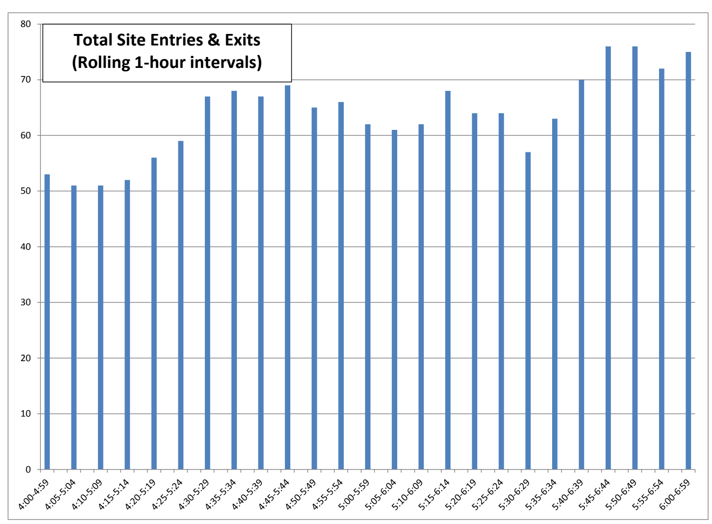
Peak-Hour Vehicle-Trip Generation

	Actual (Collected)		ITE-Estimated	
	AM	PM	AM	PM
Reported Vehicle Occupancy*	1.17	1.17	N/A	N/A
Vehicle-Trips	44	50	33	43
Trip Rate (/1000 GSF)	**0.40**	**0.46**	**0.30**	**0.39**

*Vehicle occupancy from direct observations at this site was 1.17 in the AM period and 1.15 in the PM period.



AM Peak Hour: 8:45-9:44 a.m.



PM Peak Hour: 5:50-6:49 p.m.

STUDY LOCATION 7.1: PEGASUS (RESIDENTIAL)
Address: 612 S. Flower Street
City: Los Angeles, CA
Data Collection Date: Wednesday, May 2, 2012

Photo by Texas A&M Transportation Institute

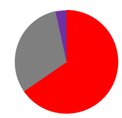
Brief Description: Pegasus Apartments is a 13-floor high-rise rental apartment building located in the southern part of Downtown Los Angeles. It occupies one half of a typical downtown LA city block. The building has three separate parking areas located in the basement and second and third floors. The Metrorail 7th Street/Metro Center Station is slightly over two blocks away, and bus service is available from several nearby routes. In addition, wide sidewalks with signalized crosswalks are available to serve the high amount of pedestrian activity near this location. The building has a restaurant on the corner of the ground floor, but this restaurant was excluded from the survey.

Site Information

ITE Land Use Code and classification	222 (Mid- to High- Density Residential)
Size of targeted land use (or building)	322 units
Proportion occupied (0.00 to 1.00)	.96
Residential population within a 0.5-mile, straight-line radius	12,596
Jobs within a 0.5-mile, straight-line radius	78,683
Straight-line distance to center of central business district (CBD)	0.16 miles (Los Angeles)
Average building setback distance from each door to closest sidewalk	0 feet
Metered on-street parking within a 0.1-mile, straight-line radius	Yes
PM peak-hour bus line stops within a 0.25-mile, straight-line radius	168
PM peak-hour passenger train line stops within a 0.5-mile, straight-line radius	6
Proportion of site area covered by surface parking lots (0.00 to 1.00)	0.00

Peak-Hour Person-Trip Generation

	Actual (Collected)	
	AM	PM
Automobile	42	
Walk	89	
Public Transit	5	
Bicycle	0	
Total	**136**	

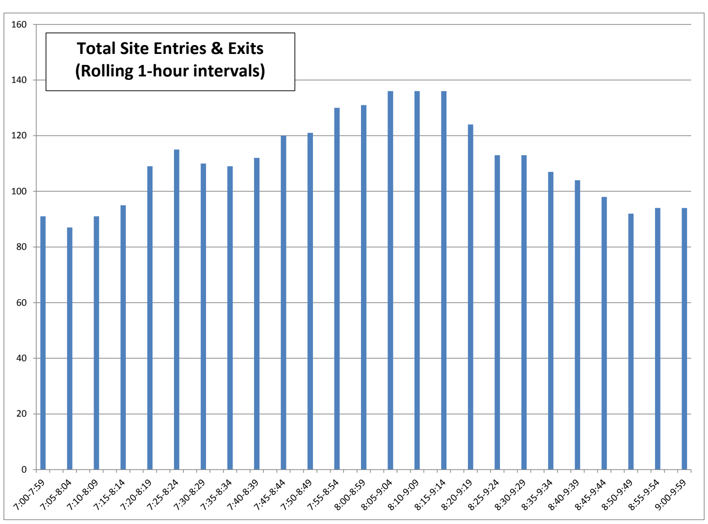


AM

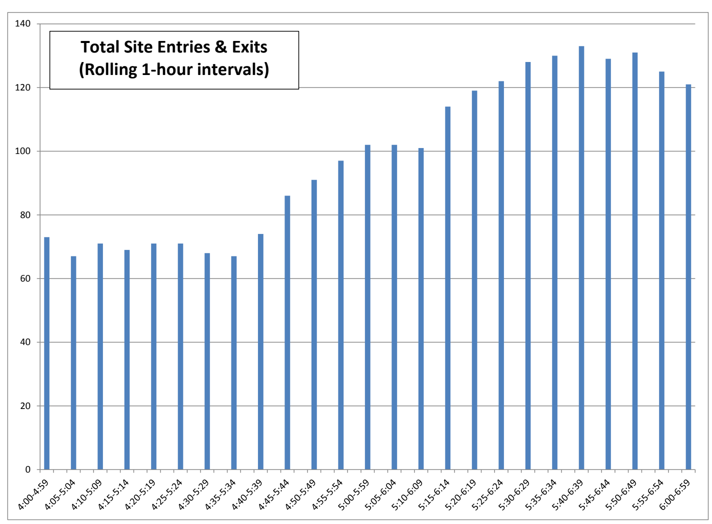
N/A **PM**

Peak-Hour Vehicle-Trip Generation

	Actual (Collected)		ITE-Estimated	
	AM	PM	AM	PM
Reported Vehicle Occupancy	1.18	1.18	N/A	N/A
Vehicle-Trips	36	N/A	92	108
Trip Rate (/1000 GSF)	**0.12**	**N/A**	**0.30**	**0.35**



AM Peak Hour: 8:10-9:09 a.m.



PM Peak Hour: 5:40-6:39 p.m.

STUDY LOCATION 8.1: PASEO COLORADO (RETAIL)

Address: 280 E. Colorado Boulevard
City: Pasadena, CA
Data Collection Date: Thursday, May 3, 2012

Photo by Texas A&M Transportation Institute

Brief Description: Paseo Colorado is a regional shopping center that includes retail, restaurant, grocery, and a theater on two levels. The largest tenant in the surveyed section is Macy's, which is the only department store in Paseo Colorado. There is a three-level underground parking structure to provide parking for this large complex, with separate parking for The Terraces apartments that are also located on the site. There is ample pedestrian access through Macy's as well as two pedestrian concourses that serve many of the other retail stores. The closest Metrorail station is within 0.25 miles, and many bus routes operate along the perimeter of Paseo Colorado. There are ground-floor businesses facing the outside of the property on the north side, but those were excluded from the study.

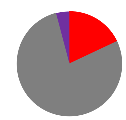
Site Information

ITE Land Use Code and classification	820 (Commercial Goods Retail)
Size of targeted land use (or building)	497,564 GSF
Proportion occupied (0.00 to 1.00)	N/A
Residential population within a 0.5-mile, straight-line radius	8,454
Jobs within a 0.5-mile, straight-line radius	22,589
Straight-line distance to center of central business district (CBD)	9.23 miles (Los Angeles)
Average building setback distance from each door to closest sidewalk	0 feet
Metered on-street parking within a 0.1-mile, straight-line radius	Yes
PM peak-hour bus line stops within a 0.25-mile, straight-line radius	18
PM peak-hour passenger train line stops within a 0.5-mile, straight-line radius	2
Proportion of site area covered by surface parking lots (0.00 to 1.00)	0.00

Peak-Hour Person-Trip Generation

	Actual (Collected)	
	AM	PM
Automobile		1208
Walk		279
Public Transit		64
Bicycle		0
Total		**1551**

N/A **AM**



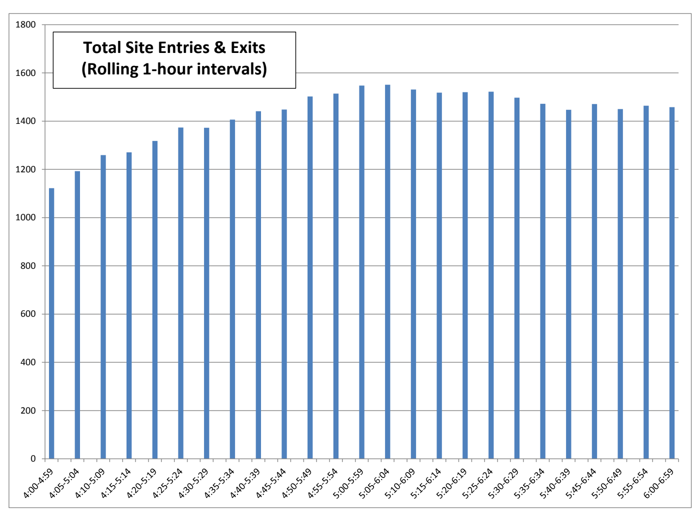
PM

Peak-Hour Vehicle-Trip Generation

	Actual (Collected)		ITE-Estimated	
	AM	PM	AM	PM
Reported Vehicle Occupancy*	N/A	1.57	N/A	N/A
Vehicle-Trips	N/A	770	498	1856
Trip Rate (/1000 GSF)	**N/A**	**1.547**	**1.00**	**3.73**

*Vehicle occupancy from direct observations at this site was 1.39 in the PM period.

N/A **AM**



PM Peak Hour: 5:05-6:04 p.m.

STUDY LOCATION 9.1: THE SIERRA (RESIDENTIAL)
Address: 311 Oak Street
City: Oakland, CA
Data Collection Date: Tuesday, May 8, 2012

Source: Google Maps

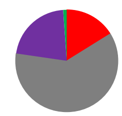
Brief Description: The Sierra is a four-story building with 219 loft-style condominiums. It located a few blocks east of the restaurants and retail shops in Oakland's Jack London District. The Sierra is 0.3 miles west of the Oakland-Jack London Amtrak train station (which also serves commuter trains on the Capitol Corridor route) and 0.3 miles south of the Lake Merritt BART station. The building has underground parking that can be accessed by two entrances on the east side and two entrances on the west side. There is a small coffee shop, convenience market, and several small offices on the ground floor, but these uses were not included in the study.

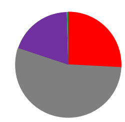
Site Information

ITE Land Use Code and classification	223 (Mid- to High- Density Residential)
Size of targeted land use (or building)	224 units
Proportion occupied (0.00 to 1.00)	0.98
Residential population within a 0.5-mile, straight-line radius	5,977
Jobs within a 0.5-mile, straight-line radius	12,892
Straight-line distance to center of central business district (CBD)	0.76 miles (Oakland)
Average building setback distance from each door to closest sidewalk	0 feet
Metered on-street parking within a 0.1-mile, straight-line radius	No
PM peak-hour bus line stops within a 0.25-mile, straight-line radius	13
PM peak-hour passenger train line stops within a 0.5-mile, straight-line radius	15
Proportion of site area covered by surface parking lots (0.00 to 1.00)	0.00

Peak-Hour Person-Trip Generation

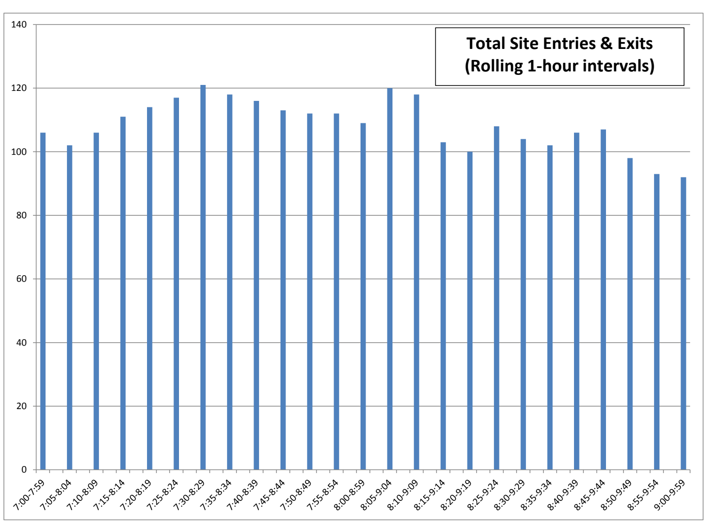
	Actual (Collected)	
	AM	PM
Automobile	74	90
Walk	20	43
Public Transit	26	32
Bicycle	1	1
Total	**121**	**166**


AM

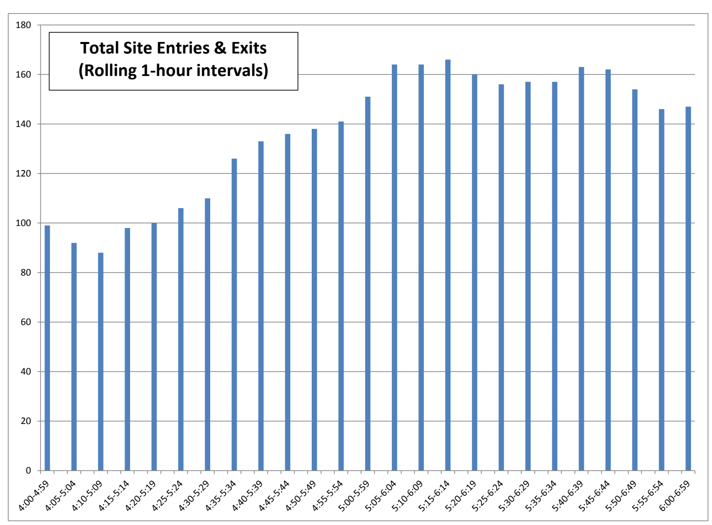

PM

Peak-Hour Vehicle-Trip Generation

	Actual (Collected)		ITE-Estimated	
	AM	PM	AM	PM
Reported Vehicle Occupancy	1.47	1.47	N/A	N/A
Vehicle-Trips	50	61	66	86
Trip Rate (/1000 GSF)	**0.23**	**0.28**	**0.30**	**0.39**



AM Peak Hour: 7:30-8:29 a.m.



PM Peak Hour: 5:15-6:14 p.m.

STUDY LOCATION 10.1: 180 GRAND AVENUE (OFFICE)
Address: 180 Grand Avenue
City: Oakland, CA
Data Collection Date: Tuesday, May 8, 2012

Source: Google Maps

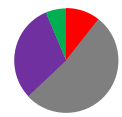
Brief Description: Located in the business center area on the northwest side of Lake Merritt, 180 Grand is a fifteen-story office building. It is on a bus route and is approximately 0.5 miles from the 19th Street Oakland BART station. A shuttle bus is available to take office patrons to the BART station. The property itself does not have any off-street parking, but 380 parking stalls are provided in a structure across 23rd Street to the northwest of the building.

Site Information

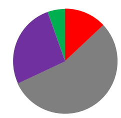
ITE Land Use Code and classification	710 (Office)
Size of targeted land use (or building)	277,789 GSF
Proportion occupied (0.00 to 1.00)	.63
Residential population within a 0.5-mile, straight-line radius	13,216
Jobs within a 0.5-mile, straight-line radius	19,225
Straight-line distance to center of central business district (CBD)	0.64 miles (Oakland)
Average building setback distance from each door to closest sidewalk	3 feet
Metered on-street parking within a 0.1-mile, straight-line radius	Yes
PM peak-hour bus line stops within a 0.25-mile, straight-line radius	41
PM peak-hour passenger train line stops within a 0.5-mile, straight-line radius	3
Proportion of site area covered by surface parking lots (0.00 to 1.00)	0.00

Peak-Hour Person-Trip Generation

	Actual (Collected)	
	AM	PM
Automobile	96	79
Walk	20	19
Public Transit	56	38
Bicycle	12	8
Total	**184**	**143**



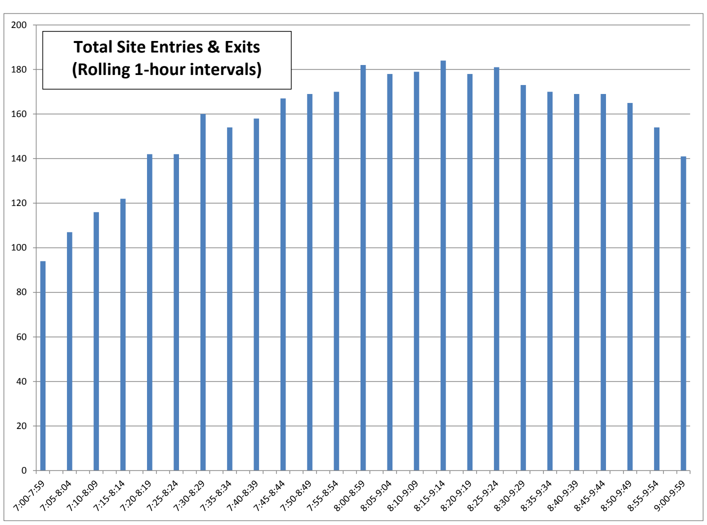
AM



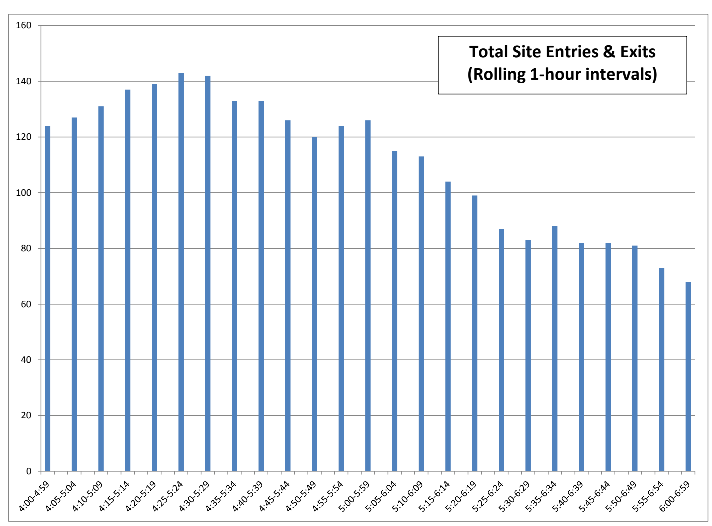
PM

Peak-Hour Vehicle-Trip Generation

	Actual (Collected)		ITE-Estimated	
	AM	PM	AM	PM
Reported Vehicle Occupancy	1.21	1.21	N/A	N/A
Vehicle-Trips	80	65	271	261
Trip Rate (/1000 GSF)	**0.455**	**0.371**	**1.55**	**1.49**



AM Peak Hour: 8:15-9:14 a.m.



PM Peak Hour: 4:25-5:24 p.m.

STUDY LOCATION 11.1: ARCHSTONE AT DEL MAR STATION (RESIDENTIAL)
Address: 265 Arroyo Parkway
City: Pasadena, CA
Data Collection Date: Tuesday, May 8, 2012


Source: Google Maps

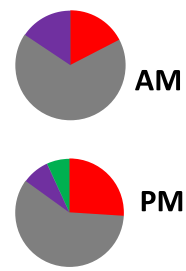
Brief Description: Archstone at Del Mar Station is a four-building rental apartment complex located adjacent to the Del Mar Station of the Metrorail Gold Line. Two Archstone buildings are on either side of the tracks. In addition to the apartments, the development also includes office and retail space in the northwest building, a small unoccupied retail space in the southeast building, and two restaurants in a revitalized historic railroad depot building. The study includes only the two east side apartment buildings. There is underground parking, and walkways connect the apartments to the station.

Site Information

ITE Land Use Code and classification	223 ()
Size of targeted land use (or building)	235 Units
Proportion occupied (0.00 to 1.00)	.94
Residential population within a 0.5-mile, straight-line radius	7,657
Jobs within a 0.5-mile, straight-line radius	16,377
Straight-line distance to center of central business district (CBD)	8.89 miles (Los Angeles)
Average building setback distance from each door to closest sidewalk	27 feet
Metered on-street parking within a 0.1-mile, straight-line radius	Yes
PM peak-hour bus line stops within a 0.25-mile, straight-line radius	34
PM peak-hour passenger train line stops within a 0.5-mile, straight-line radius	2
Proportion of site area covered by surface parking lots (0.00 to 1.00)	0.00

Peak-Hour Person-Trip Generation

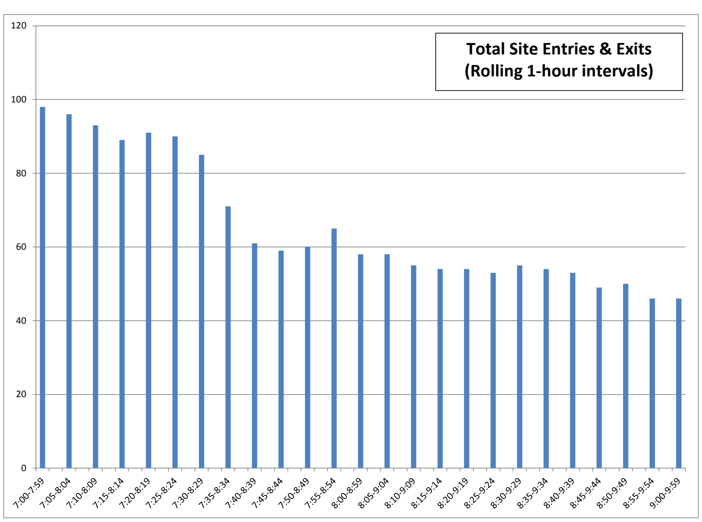
	Actual (Collected)	
	AM	PM
Automobile	66	60
Walk	17	27
Public Transit	15	8
Bicycle	0	7
Total	**98**	**102**



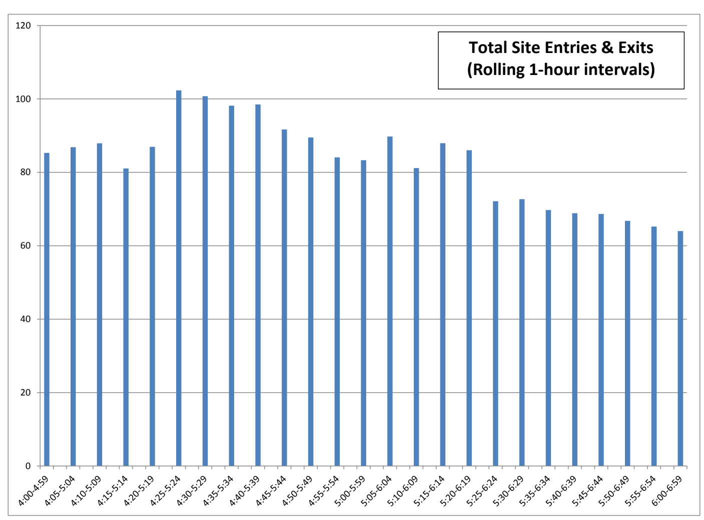
Peak-Hour Vehicle-Trip Generation

	Actual (Collected)		ITE-Estimated	
	AM	PM	AM	PM
Reported Vehicle Occupancy*	1.31	1.31	N/A	N/A
Vehicle-Trips	50	46	66	86
Trip Rate (/1000 GSF)	**0.23**	**0.21**	**0.30**	**0.39**

*Vehicle occupancy from direct observations at this site was 1.11 in the AM period and 1.12 in the PM period.



AM Peak Hour: 7:00-7:59 a.m.



PM Peak Hour: 4:25-5:24 p.m.

STUDY LOCATION 12.1: TERRACES AT EMERY STATION (RESIDENTIAL)
Address: 5855 Horton Street
City: Emeryville, CA
Data Collection Date: Wednesday, May 9, 2012

Source: Google Maps

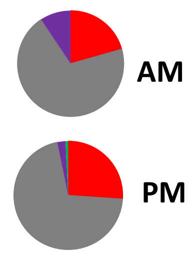
Brief Description: The Terraces is a 101-unit, five-story residential complex located five miles from the Oakland central business district. It is adjacent to the Emeryville Amtrak station, which serves 90,000 passengers per day as San Francisco's national rail stop and also serves commuter trains on the Capitol Corridor route. It is also near the east side of the Bay Bridge, which connects Oakland to San Francisco. The loft-style condominiums are located above a three-story parking structure. Two of the four parking levels are for residents, and the other two provide public parking for nearby offices and the Amtrak station. People who used public parking but did not access the Terraces residences were not considered in the trip generation analysis below.

Site Information

ITE Land Use Code and classification	223 (Mid- to High- Density Residential)
Size of targeted land use (or building)	101 Units
Proportion occupied (0.00 to 1.00)	1.00
Residential population within a 0.5-mile, straight-line radius	6,868
Jobs within a 0.5-mile, straight-line radius	10,308
Straight-line distance to center of central business district (CBD)	2.69 miles (Oakland)
Average building setback distance from each door to closest sidewalk	5 feet
Metered on-street parking within a 0.1-mile, straight-line radius	No
PM peak-hour bus line stops within a 0.25-mile, straight-line radius	5
PM peak-hour passenger train line stops within a 0.5-mile, straight-line radius	13
Proportion of site area covered by surface parking lots (0.00 to 1.00)	0.00

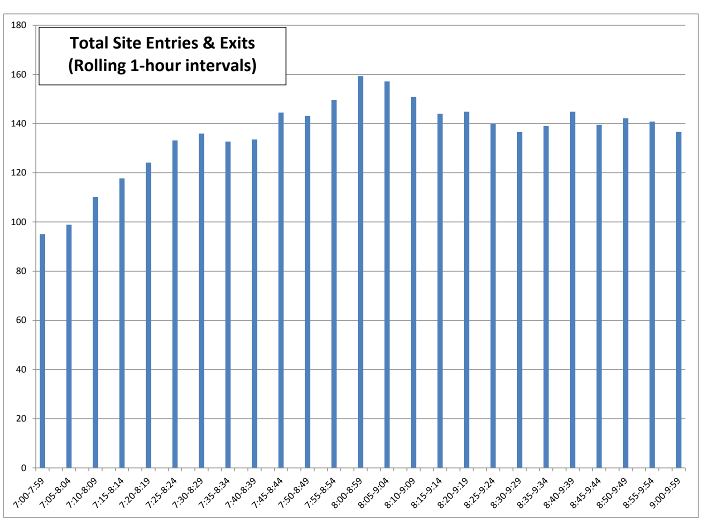
Peak-Hour Person-Trip Generation

	Actual (Collected)	
	AM	PM
Automobile	112	98
Walk	33	36
Public Transit	15	3
Bicycle	0	1
Total	**159**	**138**

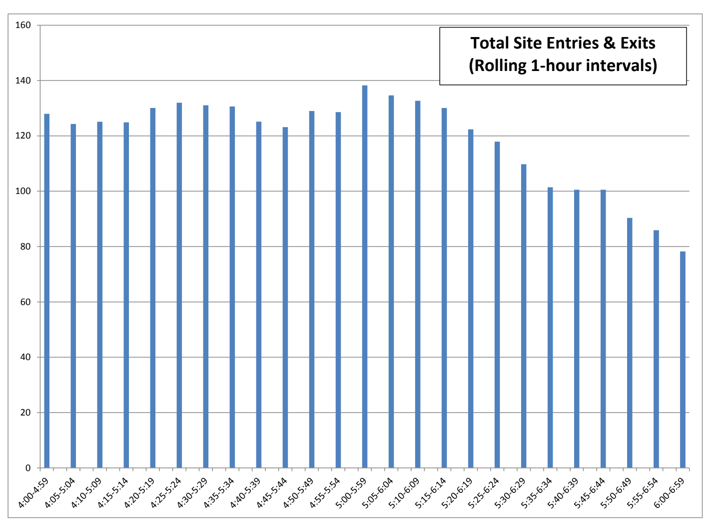


Peak-Hour Vehicle-Trip Generation

	Actual (Collected)		ITE-Estimated	
	AM	PM	AM	PM
Reported Vehicle Occupancy	1.12	1.12	N/A	N/A
Vehicle-Trips	100	87	30	39
Trip Rate (/1000 GSF)	**0.99**	**0.86**	**0.30**	**0.39**



AM Peak Hour: 8:00-8:59 a.m.



PM Peak Hour: 5:00-5:59 p.m.

STUDY LOCATION 13.1: HOLLY STREET VILLAGE
Address: 151 E. Holly Street
City: Pasadena, CA
Data Collection Date: Wednesday, May 9, 2012

Brief Description: Holly Street Village is a transit-oriented development in Pasadena located in the northern part of Downtown Pasadena. It is a single complex composed of several multi-story rental apartments. There is a small amount of partially-occupied retail space near the main entrance, but that was excluded from the study. The Metrorail Gold Line Memorial Park Station is located below the Holly Street Village buildings.

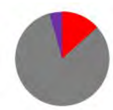
Photo by Texas A&M Transportation Institute

Site Information

ITE Land Use Code and classification	223 (Mid-to-high Density Residential)
Size of targeted land use (or building)	374 units
Proportion occupied (0.00 to 1.00)	0.95
Residential population within a 0.5-mile, straight-line radius	7,948
Jobs within a 0.5-mile, straight-line radius	22,705
Straight-line distance to center of central business district (CBD)	9.24 miles
Average building setback distance from each door to closest sidewalk	209 feet
Metered on-street parking within a 0.1-mile, straight-line radius	Yes
PM peak-hour bus line stops within a 0.25-mile, straight-line radius	53
PM peak-hour passenger train line stops within a 0.5-mile, straight-line radius	2
Proportion of site area covered by surface parking lots (0.00 to 1.00)	0

Peak-Hour Person-Trip Generation

	Actual (Collected)	
	AM	PM
Automobile	144	125
Pedestrian	23	58
Public Transit	8	1
Bicycle	0	0
Total	**175**	**184**



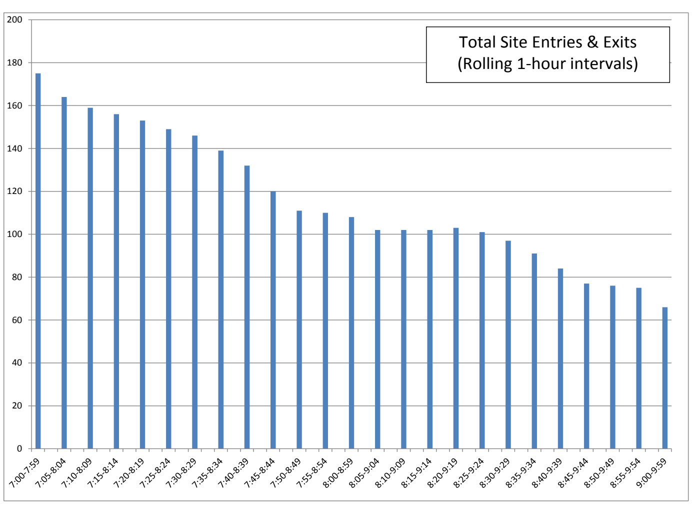
AM

PM

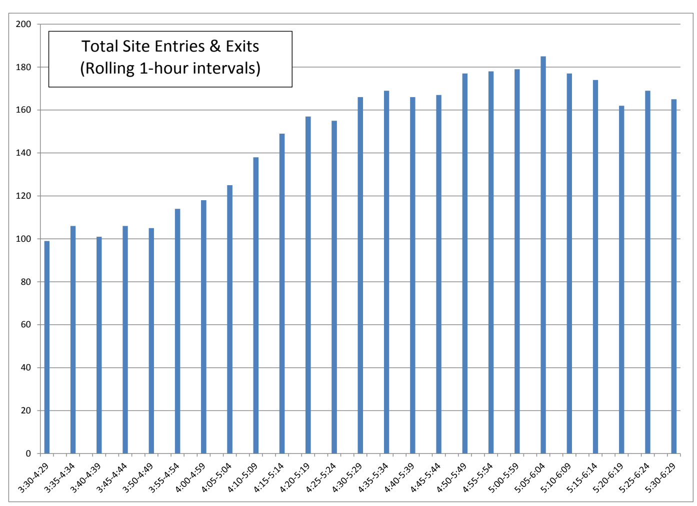
Peak-Hour Vehicle-Trip Generation

	Actual (Collected)		ITE-Estimated	
	AM	PM	AM	PM
Reported Vehicle Occupancy*	1.33	1.33		
Vehicle-Trips	108	94	107	139
Trip Rate (/1000 GSF)	**0.30**	**0.27**	**0.30**	**0.39**

*Vehicle occupancy from direct observations at this site was 1.19 in the AM period and 1.21 in the PM period.



AM Peak Hour: 7:00-7:59 a.m.



PM Peak Hour: 5:05-6:04 p.m.

STUDY LOCATION 14.1: EMERY STATION EAST
Address: 5885 Hollis Street
City: Emeryville, CA
Data Collection Date: Thursday, May 10, 2012

Source: Google Maps

Brief Description: This office building covers over 245,000 square feet and is located near the east end of the Bay Bridge that connects Oakland to San Francisco. Emery Station East is two blocks from the Emeryville Amtrak station, which serves 90, 000 passengers per day as San Francisco's national rail stop and also serves commuter trains on the Capitol Corridor route. There are several other office buildings, a residential building, and ground-floor restaurants within several blocks of Emery Station East.

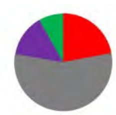
Site Information

ITE Land Use Code and classification	710 (General Office)
Size of targeted land use (or building)	247,619 GSF
Proportion occupied (0.00 to 1.00)	0.95
Residential population within a 0.5-mile, straight-line radius	7,483
Jobs within a 0.5-mile, straight-line radius	9,620
Straight-line distance to center of central business district (CBD)	2.69 miles
Average building setback distance from each door to closest sidewalk	8 feet
Metered on-street parking within a 0.1-mile, straight-line radius	No
PM peak-hour bus line stops within a 0.25-mile, straight-line radius	5
PM peak-hour passenger train line stops within a 0.5-mile, straight-line radius	13
Proportion of site area covered by surface parking lots (0.00 to 1.00)	0.00

Peak-Hour Person-Trip Generation

	Actual (Collected)	
	AM	PM
Automobile	151	140
Pedestrian	39	55
Public Transit	67	35
Bicycle	41	21
Total	**298**	**251**

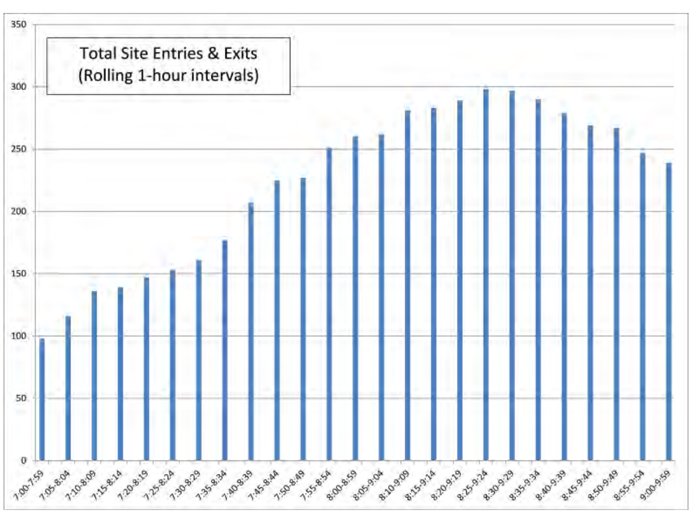
AM



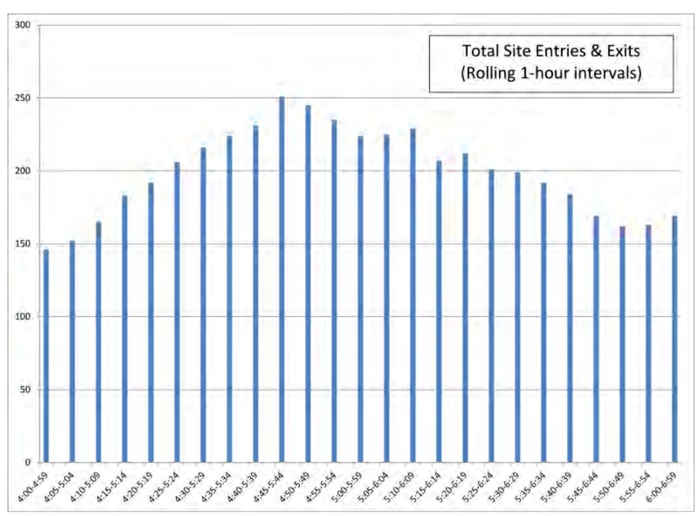
PM

Peak-Hour Vehicle-Trip Generation

	Actual (Collected)		ITE-Estimated	
	AM	PM	AM	PM
Reported Vehicle Occupancy	1.14	1.14	N/A	N/A
Vehicle-Trips	133	123	365	351
Trip Rate (/1000 GSF)	**0.565**	**0.521**	**1.55**	**1.49**

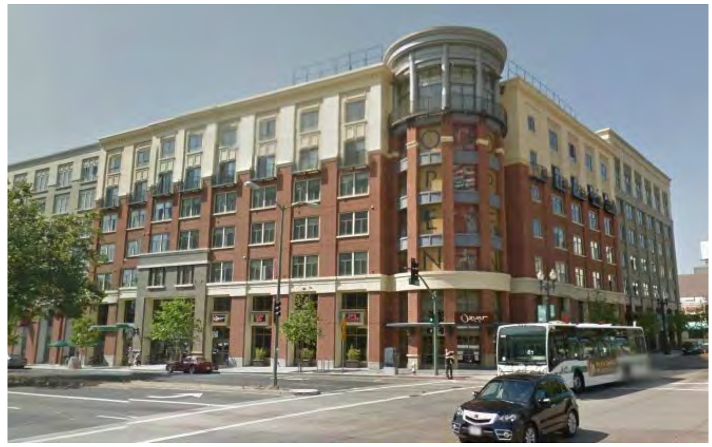


AM Peak Hour: 8:25-9:24 a.m.



PM Peak Hour: 4:45-5:44 p.m.

STUDY LOCATION 15.1: BROADWAY GRAND (RESIDENTIAL)
Address: 438 W. Grand Avenue
City: Oakland, CA
Data Collection Date: Thursday, May 10, 2012



Source: Google Maps

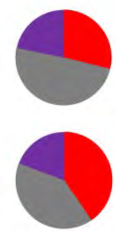
Brief Description: This six-story, 130-unit apartment complex is located in Uptown Oakland. The complex is approximately 0.3 miles from the 19th Street Oakland BART station. There are several other residential buildings, office buildings, restaurants, and bars within two blocks of Broadway Grand. The building includes a private parking garage for residents and a small public parking garage. Both parking areas are accessed from the back side of the building on 23rd Street.

Site Information

ITE Land Use Code and classification	223 (Mid-to high-Density Residential)
Size of targeted land use (or building)	130 Residential Units
Proportion occupied (0.00 to 1.00)	0.82
Residential population within a 0.5-mile, straight-line radius	11,718
Jobs within a 0.5-mile, straight-line radius	20,480
Straight-line distance to center of central business district (CBD)	0.54 miles
Average building setback distance from each door to closest sidewalk	0 feet
Metered on-street parking within a 0.1-mile, straight-line radius	Yes
PM peak-hour bus line stops within a 0.25-mile, straight-line radius	56
PM peak-hour passenger train line stops within a 0.5-mile, straight-line radius	3
Proportion of site area covered by surface parking lots (0.00 to 1.00)	0.00

Peak-Hour Person-Trip Generation

	Actual (Collected)	
	AM	PM
Automobile	36	34
Pedestrian	21	34
Public Transit	16	16
Bicycle	0	0
Total	**73**	**84**

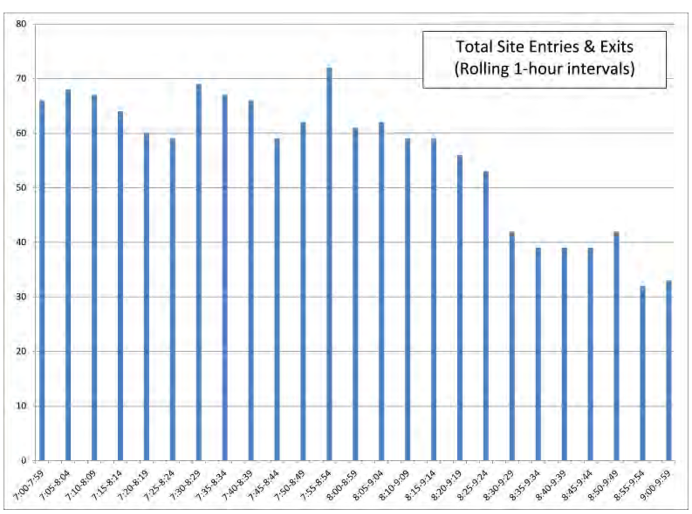


AM

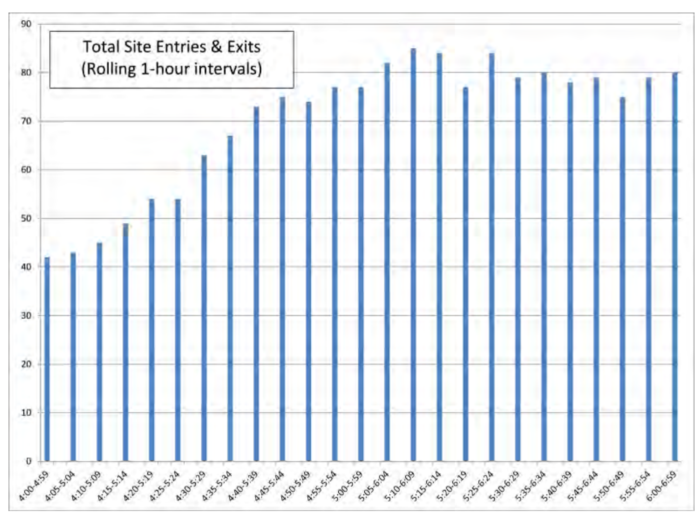
PM

Peak-Hour Vehicle-Trip Generation

	Actual (Collected)		ITE-Estimated	
	AM	PM	AM	PM
Reported Vehicle Occupancy	1.57	1.57	N/A	N/A
Vehicle-Trips	23	22	32	42
Trip Rate (/1000 GSF)	**0.210**	**0.200**	**0.30**	**0.33**



AM Peak Hour: 7:55-8:54 a.m.



PM Peak Hour: 5:10-6:09 p.m.

STUDY LOCATION 15.2: BROADWAY GRAND (COFFEE/DONUT)
Address: 438 W. Grand Avenue
City: Oakland, CA
Data Collection Date: Thursday, May 10, 2012

Brief Description: This coffee shop is located at the base of the 130-unit Broadway Grand apartment complex located in Uptown Oakland. It is approximately 0.3 miles from the 19th Street Oakland BART station. There are several residential buildings, office buildings, restaurants, and bars within two blocks of the coffee shop. The coffee shop has no designated off-street parking, but there is on-street parking in front of the store, including several free, short-term parking spaces.

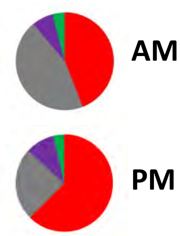
Source: Google Maps

Site Information

ITE Land Use Code and classification	936 (Coffee/Donut shop)
Size of targeted land use (or building)	1,300
Proportion occupied (0.00 to 1.00)	N/A
Residential population within a 0.5-mile, straight-line radius	11,718
Jobs within a 0.5-mile, straight-line radius	20,480
Straight-line distance to center of central business district (CBD)	0.54 miles
Average building setback distance from each door to closest sidewalk	2 feet
Metered on-street parking within a 0.1-mile, straight-line radius	Yes
PM peak-hour bus line stops within a 0.25-mile, straight-line radius	56
PM peak-hour passenger train line stops within a 0.5-mile, straight-line radius	3
Proportion of site area covered by surface parking lots (0.00 to 1.00)	0.00

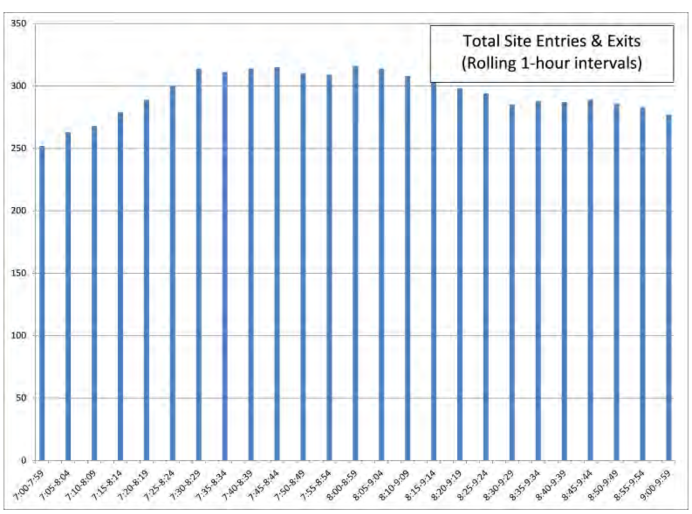
Peak-Hour Person-Trip Generation

	Actual (Collected)	
	AM	PM
Automobile	141	57
Pedestrian	139	148
Public Transit	22	23
Bicycle	13	9
Total	**316**	**237**

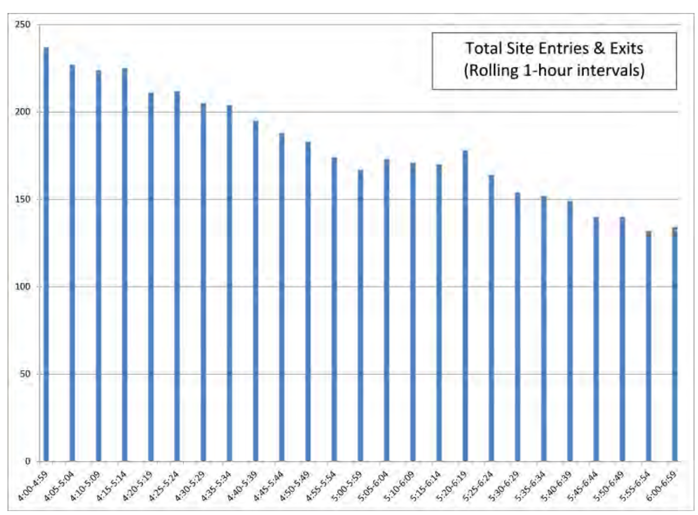


Peak-Hour Vehicle-Trip Generation

	Actual (Collected)		ITE-Estimated	
	AM	PM	AM	PM
Reported Vehicle Occupancy	1.57	1.57	N/A	N/A
Vehicle-Trips	90	36	152	53
Trip Rate (/1000 GSF)	**69.2**	**28.0**	**117**	**40.8**



AM Peak Hour: 8:00-8:59 a.m.



PM Peak Hour: 4:00-4:59 p.m.

STUDY LOCATION 16.1: TERRACES APARTMENT HOMES
Address: 375 E. Green Street
City: Pasadena, CA
Data Collection Date: Thursday, May 10, 2012

Brief Description: This gated residential community is part of the Paseo Colorado development in the heart of downtown Pasadena. The primary component of Paseo Colorado is a 550,000 square foot regional shopping center. The Terraces Apartment homes offer subterranean parking to residents, but they are somewhat difficult to access by public transit. Foothill Transit, which runs very infrequently, is the only public transportation that offers a stop near this location.

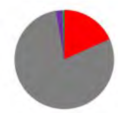
Photo by Texas A&M Transportation Institute

Site Information

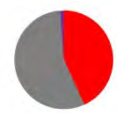
ITE Land Use Code and classification	223 (mid-to high-density residential)
Size of targeted land use (or building)	276 Units
Proportion occupied (0.00 to 1.00)	0.94
Residential population within a 0.5-mile, straight-line radius	9,926
Jobs within a 0.5-mile, straight-line radius	23,342
Straight-line distance to center of central business district (CBD)	9.26 miles
Average building setback distance from each door to closest sidewalk	14 feet
Metered on-street parking within a 0.1-mile, straight-line radius	Yes
PM peak-hour bus line stops within a 0.25-mile, straight-line radius	9
PM peak-hour passenger train line stops within a 0.5-mile, straight-line radius	2
Proportion of site area covered by surface parking lots (0.00 to 1.00)	0.00

Peak-Hour Person-Trip Generation

	Actual (Collected)	
	AM	PM
Automobile	69	47
Pedestrian	16	37
Public Transit	2	1
Bicycle	1	0
Total	**88**	**85**



AM

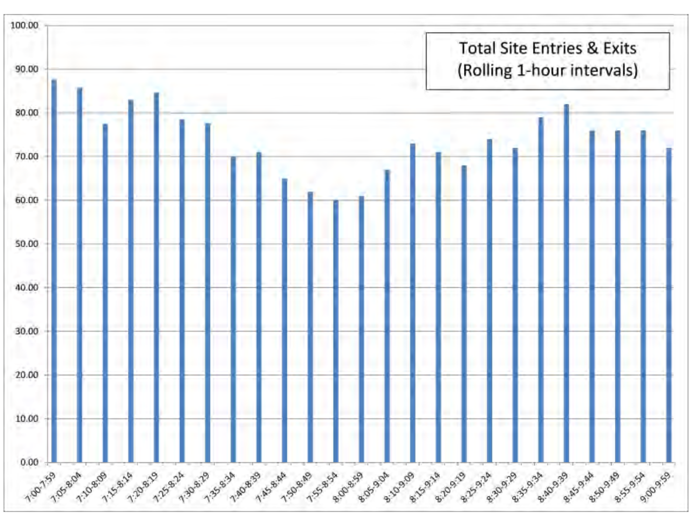


PM

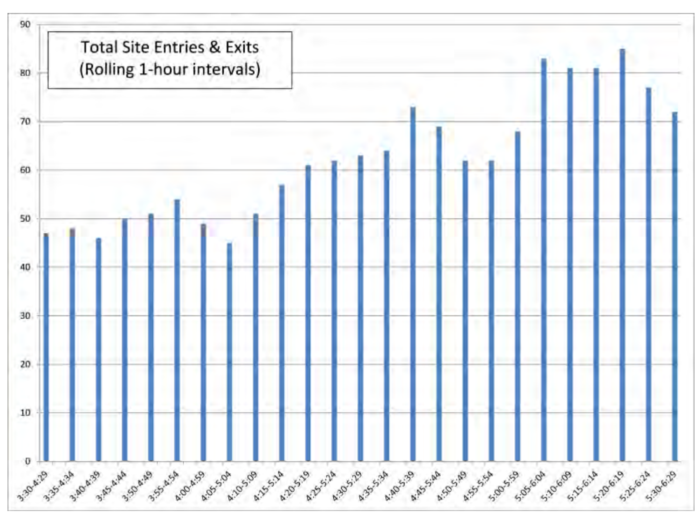
Peak-Hour Vehicle-Trip Generation

	Actual (Collected)		ITE-Estimated	
	AM	PM	AM	PM
Reported Vehicle Occupancy*	1.29	1.29	N/A	N/A
Vehicle-Trips	54	37	78	101
Trip Rate (/1000 GSF)	**0.210**	**0.140**	**0.30**	**0.39**

*Vehicle occupancy from direct observations at this site was 1.11 in the AM period.



AM Peak Hour: 7:00-7:59 a.m.



PM Peak Hour: 5:20-6:19 p.m.

STUDY LOCATION 17.1: 181 SECOND AVENUE

Address: 181 2nd Avenue

City: San Mateo, CA

Data Collection Date: Tuesday, May 15, 2012

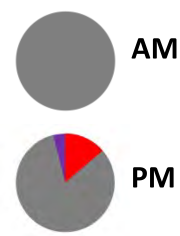
Brief Description: This six story office building is located near Downtown San Mateo. Dozens of small restaurants and shops are located within two to three blocks of the site. The building is served by a three-level parking garage that also provides public parking for a hospital complex to the west. On-street parking is metered. Bus lines are located approximately two blocks to the west and a Caltrain rail station is located approximately three blocks to the east.

Site Information

ITE Land Use Code and classification	710 (Office)
Size of targeted land use (or building)	50,600 GSF
Proportion occupied (0.00 to 1.00)	0.99
Residential population within a 0.5-mile, straight-line radius	10,919
Jobs within a 0.5-mile, straight-line radius	6,976
Straight-line distance to center of central business district (CBD)	15.9 miles
Average building setback distance from each door to closest sidewalk	7 feet
Metered on-street parking within a 0.1-mile, straight-line radius	Yes
PM peak-hour bus line stops within a 0.25-mile, straight-line radius	0
PM peak-hour passenger train line stops within a 0.5-mile, straight-line radius	6
Proportion of site area covered by surface parking lots (0.00 to 1.00)	0.00

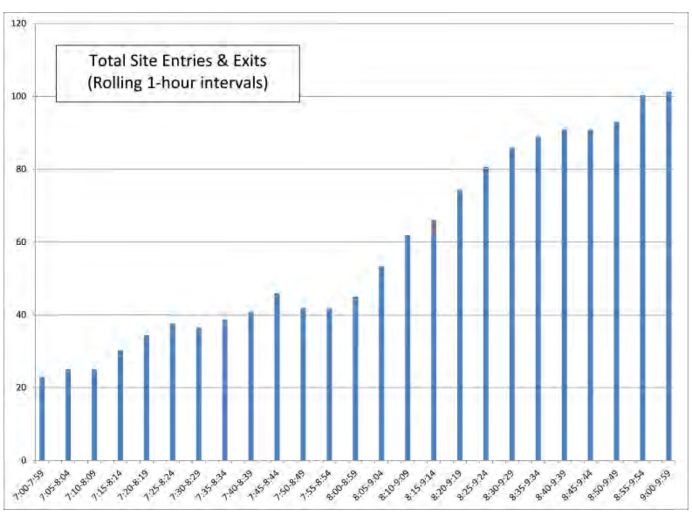
Peak-Hour Person-Trip Generation

	Actual (Collected)	
	AM	PM
Automobile	101	94
Pedestrian	0	16
Public Transit	0	5
Bicycle	0	0
Total	**101**	**114**

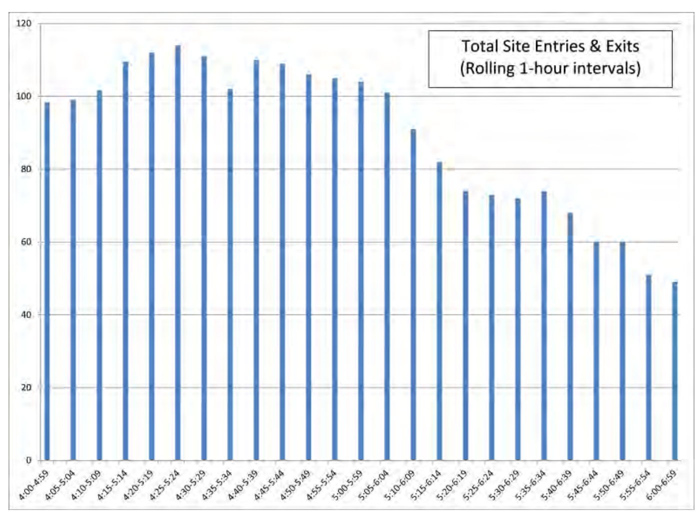


Peak-Hour Vehicle-Trip Generation

	Actual (Collected)		ITE-Estimated	
	AM	PM	AM	PM
Reported Vehicle Occupancy	1.10	1.10	N/A	N/A
Vehicle-Trips	92	85	77	74
Trip Rate (/1000 GSF)	**1.85**	**1.71**	**1.55**	**1.49**



AM Peak Hour: 9:00-9:59 a.m.



PM Peak Hour: 4:25-5:24 p.m.

STUDY LOCATION 18.1: ARGENTA
Address: 1 Polk Street
City: San Francisco, CA
Data Collection Date: Friday, May 16, 2012

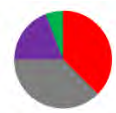
Brief Description: The Argenta residential building is located in San Francisco's Civic Center district. This complex is located near Market Street and is within two blocks of City Hall, the UN Plaza, Symphony Hall and City Auditorium. This area features numerous bus routes as well as access to BART and MUNI rail stations. Metered on-street parking is available adjacent to the building. A two-level parking garage at the base of the building provides public parking and parking for residents. People who used the public parking but did not access the Argenta residences were not considered in the trip generation analysis below.

Site Information

ITE Land Use Code and classification	223 (Mid to High-Density Residential)
Size of targeted land use (or building)	187 Units
Proportion occupied (0.00 to 1.00)	0.95
Residential population within a 0.5-mile, straight-line radius	25,704
Jobs within a 0.5-mile, straight-line radius	61,459
Straight-line distance to center of central business district (CBD)	1.09 miles
Average building setback distance from each door to closest sidewalk	0 feet
Metered on-street parking within a 0.1-mile, straight-line radius	Yes
PM peak-hour bus line stops within a 0.25-mile, straight-line radius	83
PM peak-hour passenger train line stops within a 0.5-mile, straight-line radius	21
Proportion of site area covered by surface parking lots (0.00 to 1.00)	0.00

Peak-Hour Person-Trip Generation

	Actual (Collected)	
	AM	PM
Automobile	33	29
Pedestrian	33	52
Public Transit	17	25
Bicycle	5	1
Total	**89**	**107**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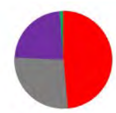
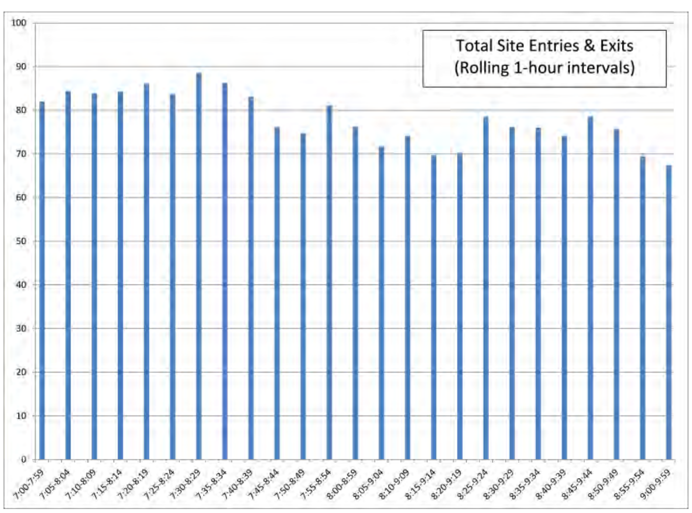
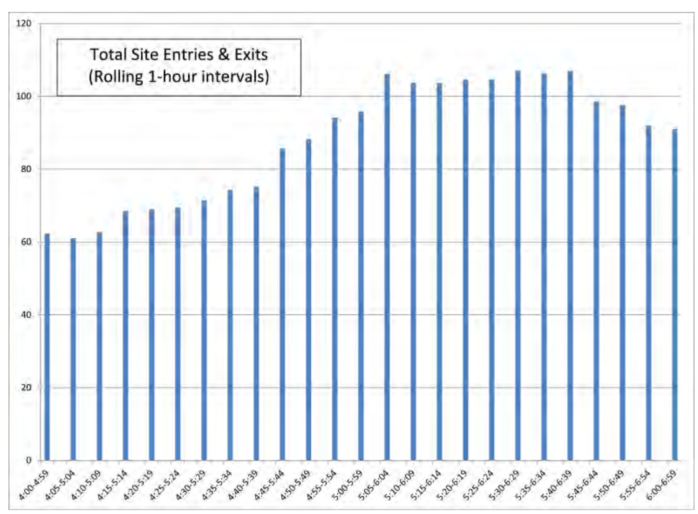

PM

Peak-Hour Vehicle-Trip Generation

	Actual (Collected)		ITE-Estimated	
	AM	PM	AM	PM
Reported Vehicle Occupancy	1.34	1.34	N/A	N/A
Vehicle-Trips	25	22	53	62
Trip Rate (/1000 GSF)	**0.14**	**0.12**	**0.30**	**0.35**



AM Peak Hour: 7:30-8:29 a.m.



PM Peak Hour: 5:30-6:29 p.m.

STUDY LOCATION 19.1: CHARLES SCHWAB BUILDING
Address: 211 Main Street
City: San Francisco, CA
Data Collection Date: Friday, May 16, 2012

Source: Google Maps

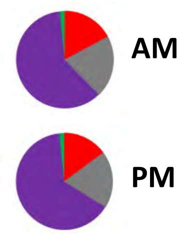
Brief Description: This 417,000 square foot office is building is located in a major employment zone on the south side of the San Francisco Financial District. There are few residences nearby, but there are many restaurants, bars, and shops on the ground level of nearby buildings. The building is served by many adjacent bus lines and is within two blocks of the Embarcadero BART station. The main entrance on the south side of the building opens to a pedestrian plaza. There are public parking garages and metered on-street parking nearby, but there is no off-street parking on site.

Site Information

ITE Land Use Code and classification	710 (Office)
Size of targeted land use (or building)	417,245 GSF
Proportion occupied (0.00 to 1.00)	0.77
Residential population within a 0.5-mile, straight-line radius	10,053
Jobs within a 0.5-mile, straight-line radius	87,332
Straight-line distance to center of central business district (CBD)	0.6 miles
Average building setback distance from each door to closest sidewalk	27 feet
Metered on-street parking within a 0.1-mile, straight-line radius	Yes
PM peak-hour bus line stops within a 0.25-mile, straight-line radius	97
PM peak-hour passenger train line stops within a 0.5-mile, straight-line radius	40
Proportion of site area covered by surface parking lots (0.00 to 1.00)	0.00

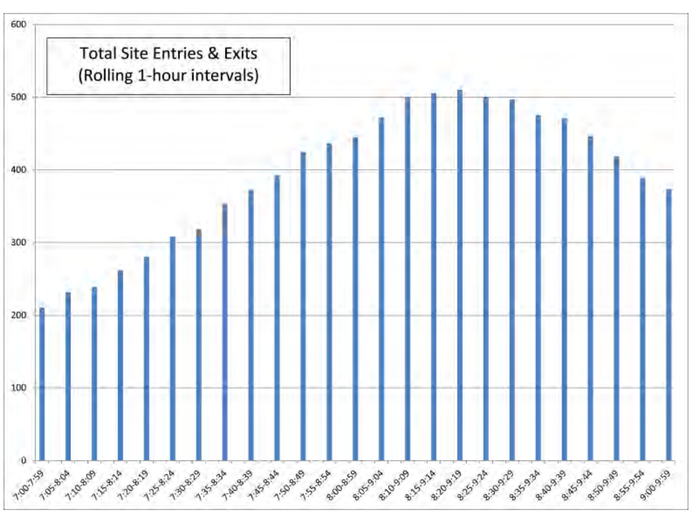
Peak-Hour Person-Trip Generation

	Actual (Collected)	
	AM	PM
Automobile	104	76
Pedestrian	88	60
Public Transit	309	259
Bicycle	8	7
Total	**510**	**401**

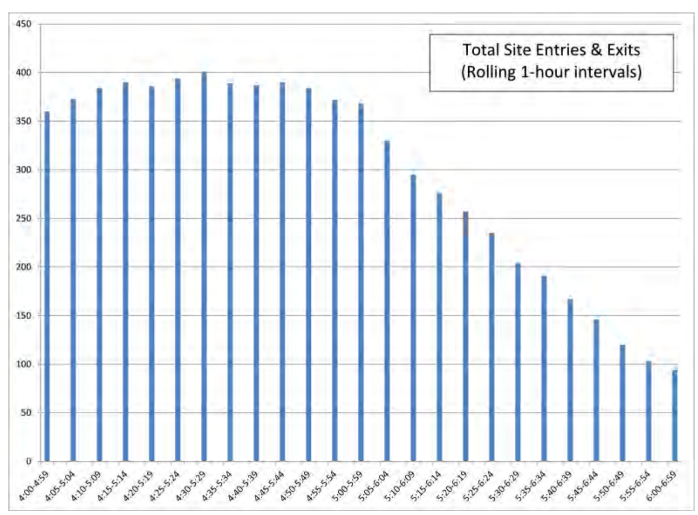


Peak-Hour Vehicle-Trip Generation

	Actual (Collected)		ITE-Estimated	
	AM	PM	AM	PM
Reported Vehicle Occupancy	1.77	1.77	N/A	N/A
Vehicle-Trips	59	43	498	479
Trip Rate (/1000 GSF)	**0.183**	**0.133**	**1.55**	**1.49**



AM Peak Hour: 8:20-9:19 a.m.



PM Peak Hour: 4:30-5:29 p.m.

STUDY LOCATION 20.1: PARK TOWER (OFFICE)
Address: 980 9th Street
City: Sacramento, CA
Data Collection Date: Tuesday, May 22, 2012

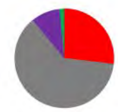
Brief Description: Park Tower is located in Downtown Sacramento. There are many restaurants, retail stores, and other office buildings nearby. Caesar Chavez Park is across the street to the east of Park Tower. Multiple bus routes serve the area around the building, and two light rail transit stops are located within two blocks of the building. There is metered on-street parking as well as a large public parking structure on the west side of the building that serves Park Tower, the adjacent library, and other land uses in the vicinity.

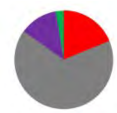
Site Information

ITE Land Use Code and classification	710 (Office)
Size of targeted land use (or building)	462,476 GSF
Proportion occupied (0.00 to 1.00)	0.90
Residential population within a 0.5-mile, straight-line radius	4,450
Jobs within a 0.5-mile, straight-line radius	54,889
Straight-line distance to center of central business district (CBD)	0.25 miles
Average building setback distance from each door to closest sidewalk	10 feet
Metered on-street parking within a 0.1-mile, straight-line radius	Yes
PM peak-hour bus line stops within a 0.25-mile, straight-line radius	255
PM peak-hour passenger train line stops within a 0.5-mile, straight-line radius	39
Proportion of site area covered by surface parking lots (0.00 to 1.00)	0.00

Peak-Hour Person-Trip Generation

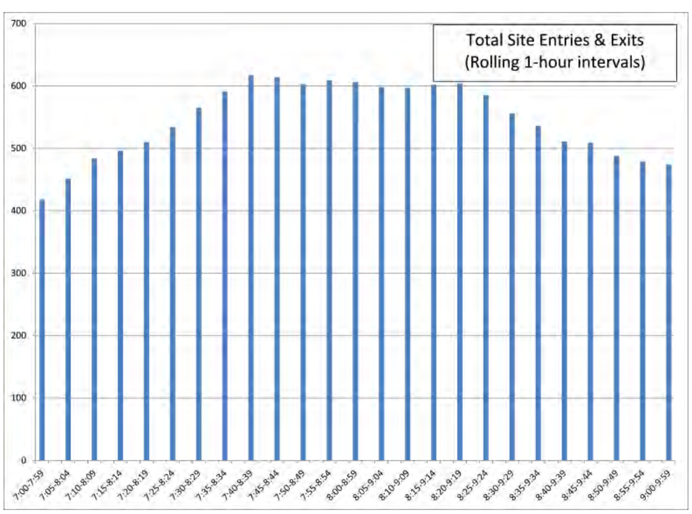
	Actual (Collected)	
	AM	PM
Automobile	383	374
Pedestrian	166	107
Public Transit	58	71
Bicycle	10	15
Total	**617**	**566**


AM

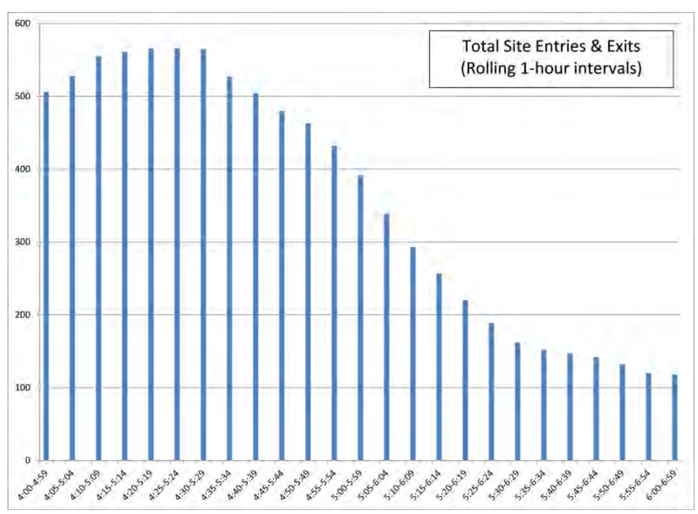

PM

Peak-Hour Vehicle-Trip Generation

	Actual (Collected)		ITE-Estimated	
	AM	PM	AM	PM
Reported Vehicle Occupancy	1.20	1.20	N/A	N/A
Vehicle-Trips	319	312	645	620
Trip Rate (/1000 GSF)	**0.767**	**0.748**	**1.55**	**1.49**



AM Peak Hour: 7:40-8:39 a.m.



PM Peak Hour: 4:25-5:24 p.m.

STUDY LOCATION 20.2: PARK TOWER (COFFEE/DONUT SHOP)
Address: 980 9th Street
City: Sacramento, CA
Data Collection Date: Tuesday, May 22, 2012

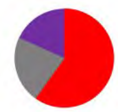
Brief Description: This coffee shop is located at the base of the Park Tower office building in downtown Sacramento. There are many restaurants, retail stores, and office buildings nearby. Caesar Chavez Park is across the street to the east of Park Tower. Multiple bus routes serve the area around the coffee shop, and two light rail transit stops are located within two blocks of the coffee shop. There is metered on-street parking in front of the coffee shop. An internal doorway connects the coffee shop directly to the office lobby.

Site Information

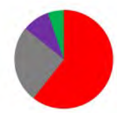
ITE Land Use Code and classification	936 (Coffee/Donut Shop)
Size of targeted land use (or building)	1,652
Proportion occupied (0.00 to 1.00)	N/A
Residential population within a 0.5-mile, straight-line radius	4,450
Jobs within a 0.5-mile, straight-line radius	54,889
Straight-line distance to center of central business district (CBD)	0.25 miles
Average building setback distance from each door to closest sidewalk	0 feet
Metered on-street parking within a 0.1-mile, straight-line radius	Yes
PM peak-hour bus line stops within a 0.25-mile, straight-line radius	255
PM peak-hour passenger train line stops within a 0.5-mile, straight-line radius	39
Proportion of site area covered by surface parking lots (0.00 to 1.00)	0.00

Peak-Hour Person-Trip Generation

	Actual (Collected)	
	AM	PM
Automobile	94	23
Pedestrian	257	55
Public Transit	79	8
Bicycle	0	5
Total	**430**	**91**



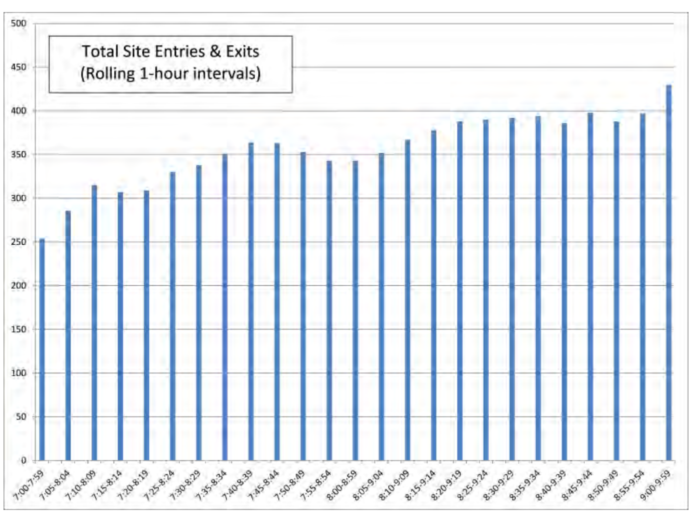
AM



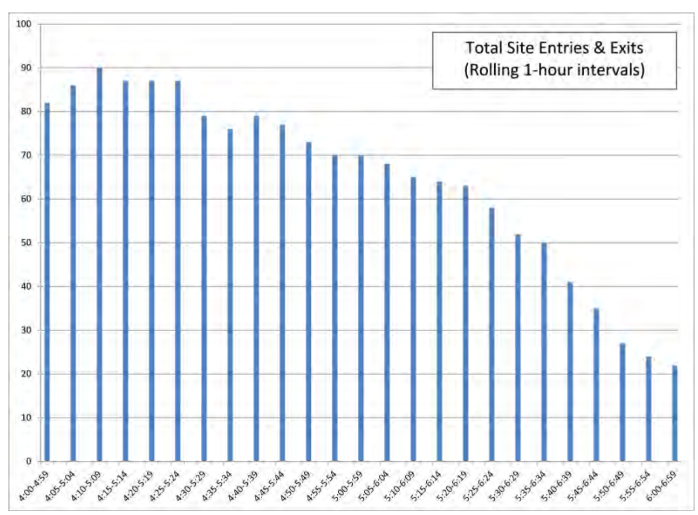
PM

Peak-Hour Vehicle-Trip Generation

	Actual (Collected)		ITE-Estimated	
	AM	PM	AM	PM
Reported Vehicle Occupancy	1.20	1.20	N/A	N/A
Vehicle-Trips	78	19	194	67
Trip Rate (/1000 GSF)	**47.4**	**11.4**	**117**	**40.8**



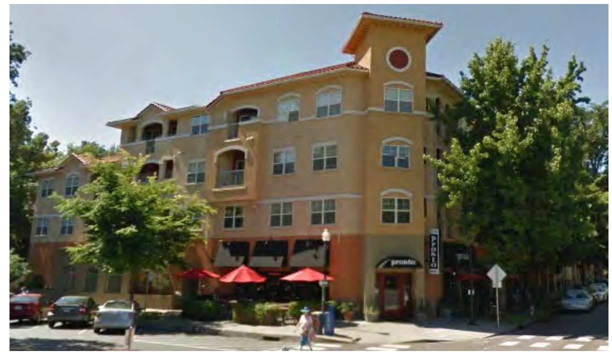
AM Peak Hour: 9:00-9:59 a.m.



PM Peak Hour: 4:10-5:09 p.m.

STUDY LOCATION 21.1: FREMONT BUILDING

Address: 1501 16th Street
City: Sacramento, CA
Data Collection Date: Tuesday, May 1st, 2012 & Tuesday, May 22nd, 2012



Source: Google Maps

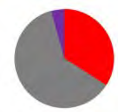
Brief Description: The Fremont Building apartment complex is located less than one mile from Downtown Sacramento and the California State Capitol. It is also less than four miles from Sacramento State University. The complex offers a gated and covered parking for residents and has first-floor retail and restaurants. On-street parking is also available. The non-residential uses were not included in the study.

Site Information

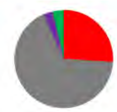
ITE Land Use Code and classification	223 (Mid- to High-Density Residential)
Size of targeted land use (or building)	69 Units
Proportion occupied (0.00 to 1.00)	0.96
Residential population within a 0.5-mile, straight-line radius	6,247
Jobs within a 0.5-mile, straight-line radius	45,004
Straight-line distance to center of central business district (CBD)	0.46 miles
Average building setback distance from each door to closest sidewalk	60 feet
Metered on-street parking within a 0.1-mile, straight-line radius	Yes
PM peak-hour bus line stops within a 0.25-mile, straight-line radius	79
PM peak-hour passenger train line stops within a 0.5-mile, straight-line radius	12
Proportion of site area covered by surface parking lots (0.00 to 1.00)	0.05

Peak-Hour Person-Trip Generation

	Actual (Collected)	
	AM	PM
Automobile	31	28
Pedestrian	17	11
Public Transit	2	1
Bicycle	0	2
Total	**50**	**42**



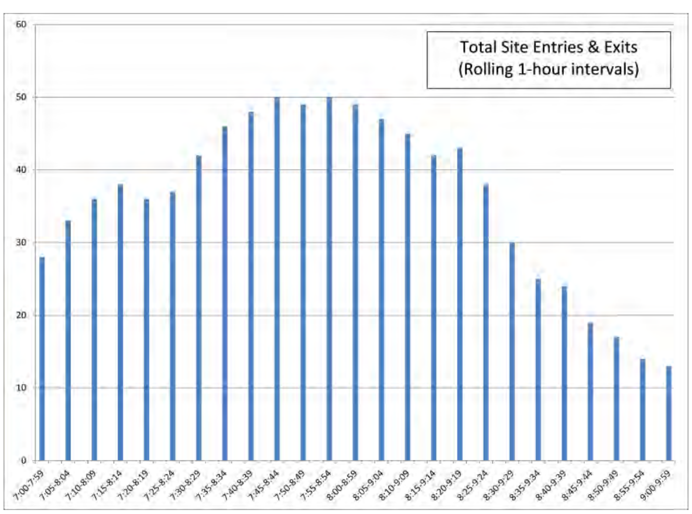
AM



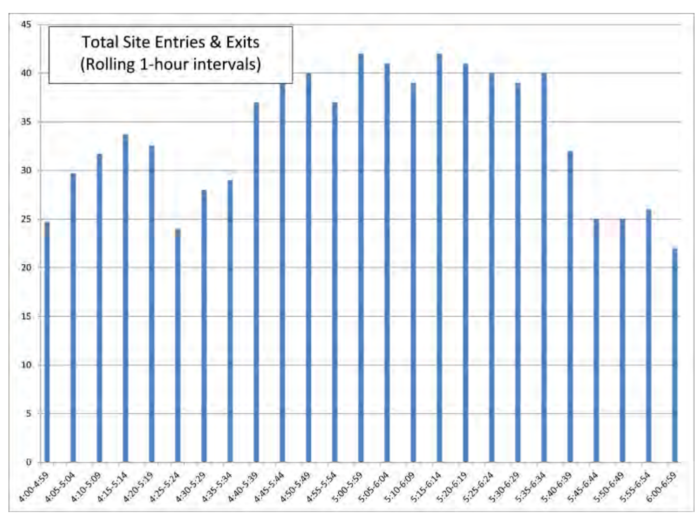
PM

Peak-Hour Vehicle-Trip Generation

	Actual (Collected)		ITE-Estimated	
	AM	PM	AM	PM
Reported Vehicle Occupancy	1.23	1.23	N/A	N/A
Vehicle-Trips	25	23	20	26
Trip Rate (/1000 GSF)	**0.38**	**0.35**	**0.30**	**0.39**

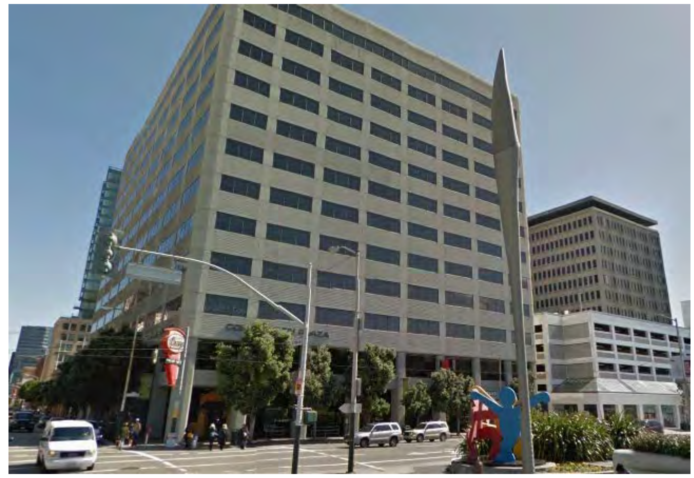


AM Peak Hour: 7:55-8:54 a.m.



PM Peak Hour: 5:15-6:14 p.m.

STUDY LOCATION 22.1: CONVENTION PLAZA (OFFICE)
Address: 201 3rd Street
City: San Francisco, CA
Data Collection Date: Wednesday, May 23, 2012


Source: Google Maps

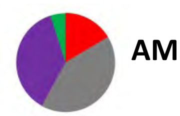
Brief Description: Convention Plaza is a 323,000 square foot office building located on the south side of the San Francisco Financial District. Land uses nearby include other offices, small retail shops, restaurants, and a convention center. The adjacent streets have metered on-street parking, and there is a multi-level public parking garage to the south of Convention Plaza. This parking garage is separated from the building by a 50-foot-wide pedestrian plaza. Convention Plaza is served by multiple bus lines on the adjacent streets and is within four blocks of the Montgomery BART station.

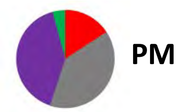
Site Information

ITE Land Use Code and classification	710 (Office)
Size of targeted land use (or building)	323,000 GSF
Proportion occupied (0.00 to 1.00)	.96
Residential population within a 0.5-mile, straight-line radius	13,841
Jobs within a 0.5-mile, straight-line radius	114,800
Straight-line distance to center of central business district (CBD)	0.24 miles
Average building setback distance from each door to closest sidewalk	37 feet
Metered on-street parking within a 0.1-mile, straight-line radius	Yes
PM peak-hour bus line stops within a 0.25-mile, straight-line radius	140
PM peak-hour passenger train line stops within a 0.5-mile, straight-line radius	32
Proportion of site area covered by surface parking lots (0.00 to 1.00)	0.00

Peak-Hour Person-Trip Generation

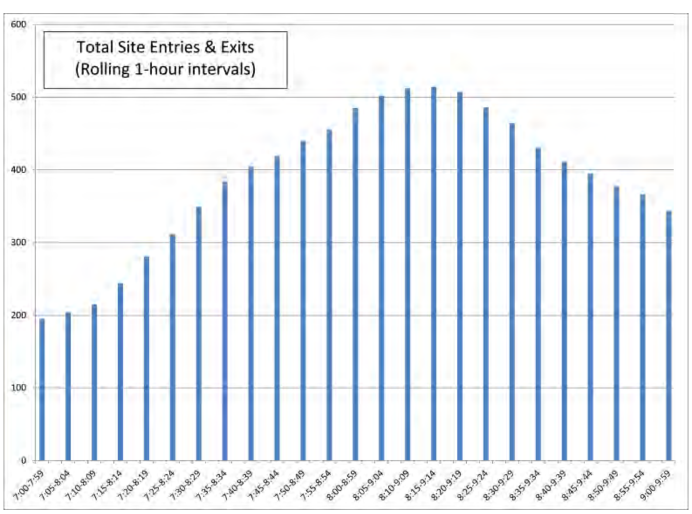
	Actual (Collected)	
	AM	PM
Automobile	214	193
Pedestrian	84	78
Public Transit	190	200
Bicycle	25	21
Total	**514**	**492**



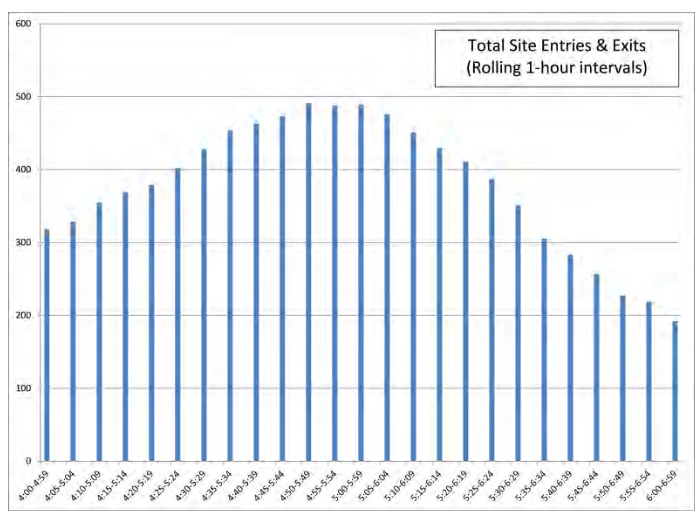


Peak-Hour Vehicle-Trip Generation

	Actual (Collected)		ITE-Estimated	
	AM	PM	AM	PM
Reported Vehicle Occupancy	1.17	1.17	N/A	N/A
Vehicle-Trips	183	165	481	462
Trip Rate (/1000 GSF)	**0.590**	**0.531**	**1.55**	**1.49**



AM Peak Hour: 8:15-9:14 a.m.



PM Peak Hour: 4:50-5:49 p.m.

STUDY LOCATION 22.2: CONVENTION PLAZA (COFFEE/DONUT SHOP)
Address: 201 3rd Street
City: San Francisco, CA
Data Collection Date: Wednesday, May 23, 2012

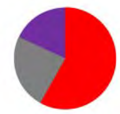
Brief Description: This coffee shop is located on the ground floor of the Convention Plaza office building. There are many office buildings, restaurants, and other small businesses within two blocks of the coffee shop. A convention center is one block west of the coffee shop. There is metered on-street parking and a bus stop on the block in front of the coffee shop.

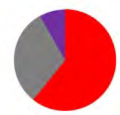
Site Information

ITE Land Use Code and classification	936 (Coffee/Donut Shop)
Size of targeted land use (or building)	1,556 GSF
Proportion occupied (0.00 to 1.00)	N/A
Residential population within a 0.5-mile, straight-line radius	13,841
Jobs within a 0.5-mile, straight-line radius	114,800
Straight-line distance to center of central business district (CBD)	0.24 miles
Average building setback distance from each door to closest sidewalk	37 feet
Metered on-street parking within a 0.1-mile, straight-line radius	Yes
PM peak-hour bus line stops within a 0.25-mile, straight-line radius	140
PM peak-hour passenger train line stops within a 0.5-mile, straight-line radius	32
Proportion of site area covered by surface parking lots (0.00 to 1.00)	0.00

Peak-Hour Person-Trip Generation*

	Actual (Collected)	
	AM	PM
Automobile	62	25
Pedestrian	151	49
Public Transit	47	7
Bicycle	0	0
Total	**260**	**81**

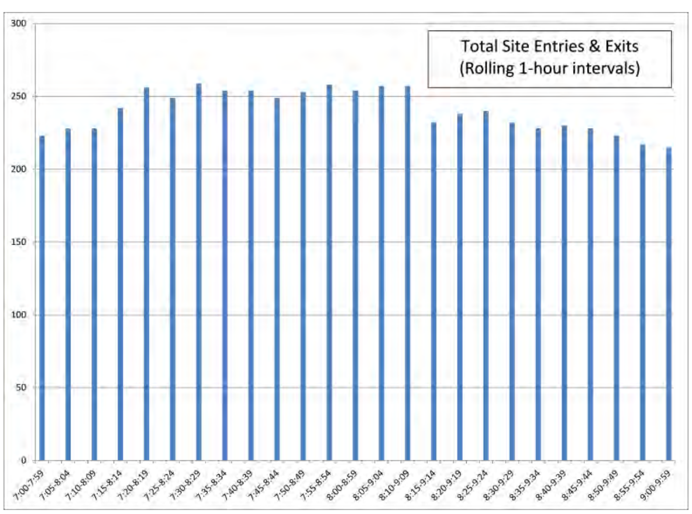

AM


PM

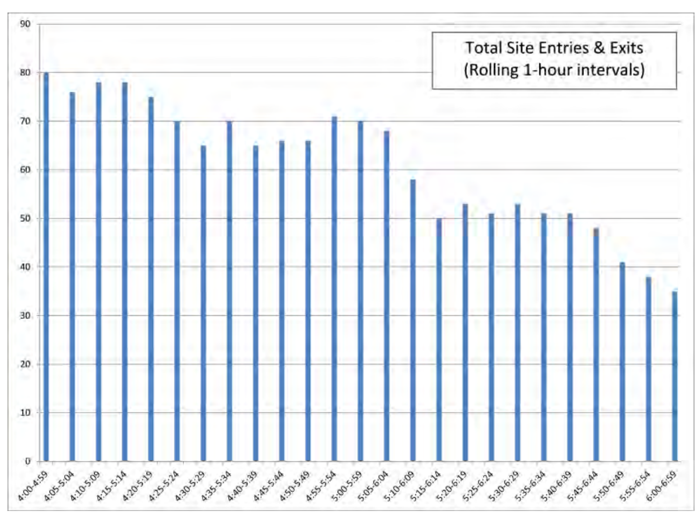
Peak-Hour Vehicle-Trip Generation*

	Actual (Collected)		ITE-Estimated	
	AM	PM	AM	PM
Reported Vehicle Occupancy	1.17	1.17	N/A	N/A
Vehicle-Trips	53	21	182	63
Trip Rate (/1000 GSF)	**33.8**	**13.6**	**117**	**40.8**

*The plaza adjacent to the coffee shop was under construction on the day of data collection. This could have reduced overall person-trip generation at the coffee shop, but this impact was probably slight, given the dense, urban context and extra signage directing customers to the store.



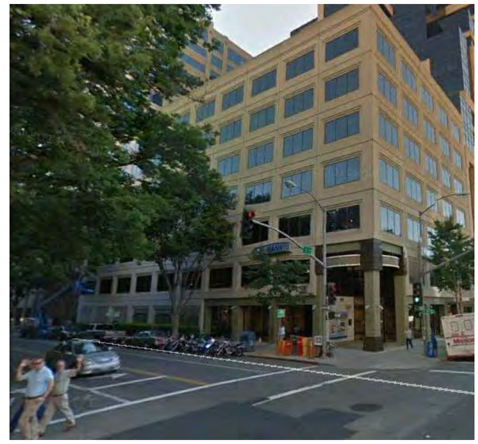
AM Peak Hour: 7:30-8:29 a.m.



PM Peak Hour: 4:00-4:59 p.m.

STUDY LOCATION 23.1: PARK PLAZA
Address: 1303 J Street
City: Sacramento, CA
Data Collection Date: Thursday, May 24, 2012

Brief Description: This seven-story office building is located in Downtown Sacramento within three blocks of the State Capitol. There are many retail stores, restaurants, and other offices nearby. Park Plaza is served by multiple bus lines and is within two blocks of a light rail stop. There are a few designated parking spaces within the building, but most drivers park off-site.



Source: Google Maps

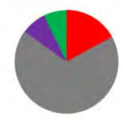
Site Information

ITE Land Use Code and classification	710 (Office)
Size of targeted land use (or building)	72,649 GSF
Proportion occupied (0.00 to 1.00)	.88
Residential population within a 0.5-mile, straight-line radius	5,109
Jobs within a 0.5-mile, straight-line radius	55,364
Straight-line distance to center of central business district (CBD)	0.14 miles
Average building setback distance from each door to closest sidewalk	5 feet
Metered on-street parking within a 0.1-mile, straight-line radius	Yes
PM peak-hour bus line stops within a 0.25-mile, straight-line radius	103
PM peak-hour passenger train line stops within a 0.5-mile, straight-line radius	16
Proportion of site area covered by surface parking lots (0.00 to 1.00)	0.00

Peak-Hour Person-Trip Generation

	Actual (Collected)	
	AM	PM
Automobile	37	36
Pedestrian	6	9
Public Transit	4	4
Bicycle	7	4
Total	**55**	**53**

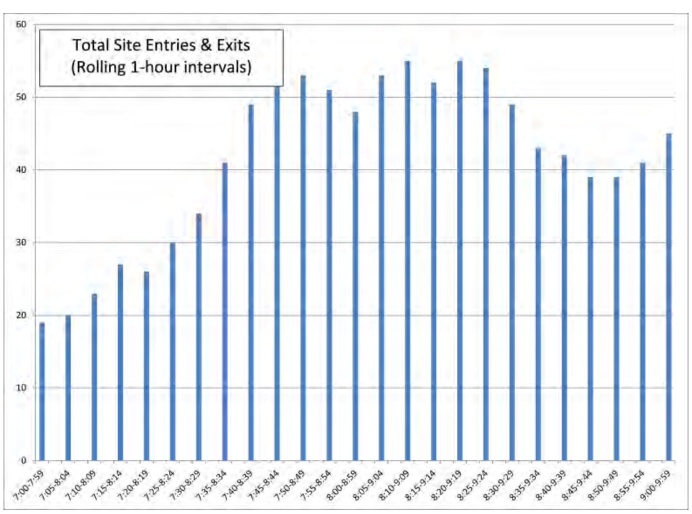
N/A **AM**



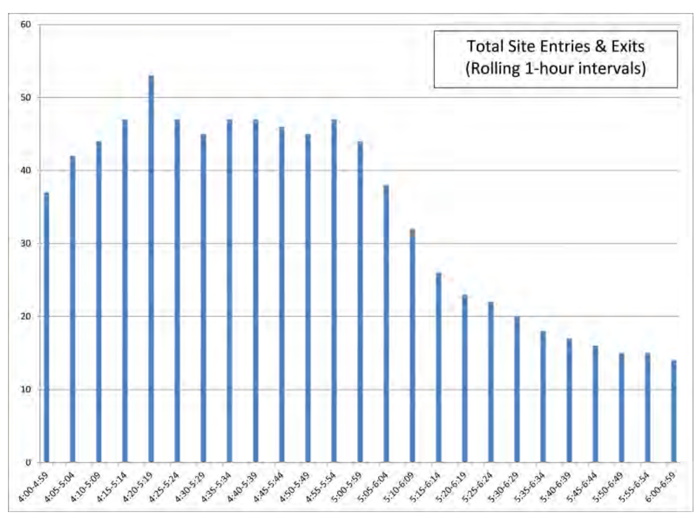
PM

Peak-Hour Vehicle-Trip Generation

	Actual (Collected)		ITE-Estimated	
	AM	PM	AM	PM
Reported Vehicle Occupancy	1.27	1.27	N/A	N/A
Vehicle-Trips	29	28	99	95
Trip Rate (/1000 GSF)	**0.458**	**0.443**	**1.55**	**1.49**



AM Peak Hour: 8:20-9:19 a.m.



PM Peak Hour: 4:20-5:19 p.m.

APPENDIX B. STANDARD DOOR COUNT FORM

Door Count Form
(Use one sheet each hour. Write start time at top of each sheet.)

Site: ___________________________________ Name: ________________________________ Date: ___________

Time [Start ____:____ am/pm]	Direction	Location:____________		Location:____________		Location:____________	
		Male	Female	Male	Female	Male	Female
:00 to :04	In						
	Out						
:05 to :09	In						
	Out						
:10 to :14	In						
	Out						
:15 to :19	In						
	Out						
:20 to :24	In						
	Out						
:25 to :29	In						
	Out						
:30 to :34	In						
	Out						
:35 to :39	In						
	Out						
:40 to :44	In						
	Out						
:45 to :49	In						
	Out						
:50 to :54	In						
	Out						
:55 to :59	In						
	Out						

APPENDIX C. STANDARD INTERCEPT SURVEY FORM

Exit Intercept Survey: As persons DEPART, intercept as they leave a specific entrance.

Interviewer Name:________________________ Cell Phone: (____)________ Building: __________________ Date: ____________ Start Time: ____:____ am pm Page ____ of ____

"Hello! Do you a have a minute to take a brief transportation survey?" (This survey is for a research project led by UC Davis for the California Department of Transportation. Feel free to decline to answer any questions you are not comfortable with.)

Time of Survey	Where are you headed now? (Check one only.)	How will you travel to get there? (Check each that applies.)		Where did you come from immediately before you came here? (Check one only.)	How did you travel here? (Check each that applies.)			Other Info (Ask all.)	Refusal?
__:__ ☐ AM ☐ PM	☐ On-Site: Name of Business/Building __________ ☐ Off-Site: Address/Nearest Intersection __________ & City (if other) ______	☐ Walk: Will you walk all the way ? ☐ Y ☐ N ☐ Auto: ☐ Drive parked car ☐ Passenger in parked car ☐ Get picked up ☐ Bus: Catch on-site? ☐ Y ☐ N ☐ Train: Catch on-site? ☐ Y ☐ N ☐ Bicycle	How many other people are travelling w/ you? ______	☐ On-Site: Name of Business/Building __________ ☐ Off-Site: Address/Nearest Intersection __________ City (if other) ______	☐ Walk: Walked all the way ? ☐ Y ☐ N ☐ Auto: Did you park? ☐ Y -On-site ☐ Y - Off-site ☐ N Did you pay for parking? ☐ Y ☐ N Did you get dropped off? ☐ Y ☐ N ☐ Bus: Did you get off at a stop on-site? ☐ Y ☐ N ☐ Train: Did you get off at a stop on-site? ☐ Y ☐ N ☐ Bicycle	How many other people travelled w/ you)? ______	What time did you arrive here? ___:___ ☐ AM ☐ PM	Home Zip Code: ______ Age: ____ Sex: ☐ M ☐ F	~Age? ____ Sex: ☐ M ☐ F
__:__ ☐ AM ☐ PM	☐ On-Site: Name of Business/Building __________ ☐ Off-Site: Address/Nearest Intersection __________ & City (if other) ______	☐ Walk: Will you walk all the way ? ☐ Y ☐ N ☐ Auto: ☐ Drive parked car ☐ Passenger in parked car ☐ Get picked up ☐ Bus: Catch on-site? ☐ Y ☐ N ☐ Train: Catch on-site? ☐ Y ☐ N ☐ Bicycle	How many other people are travelling w/ you? ______	☐ On-Site: Name of Business/Building __________ ☐ Off-Site: Address/Nearest Intersection __________ City (if other) ______	☐ Walk: Walked all the way ? ☐ Y ☐ N ☐ Auto: Did you park? ☐ Y -On-site ☐ Y - Off-site ☐ N Did you pay for parking? ☐ Y ☐ N Did you get dropped off? ☐ Y ☐ N ☐ Bus: Did you get off at a stop on-site? ☐ Y ☐ N ☐ Train: Did you get off at a stop on-site? ☐ Y ☐ N ☐ Bicycle	How many other people travelled w/ you)? ______	What time did you arrive here? ___:___ ☐ AM ☐ PM	Home Zip Code: ______ Age: ____ Sex: ☐ M ☐ F	~Age? ____ Sex: ☐ M ☐ F
__:__ ☐ AM ☐ PM	☐ On-Site: Name of Business/Building __________ ☐ Off-Site: Address/Nearest Intersection __________ & City (if other) ______	☐ Walk: Will you walk all the way ? ☐ Y ☐ N ☐ Auto: ☐ Drive parked car ☐ Passenger in parked car ☐ Get picked up ☐ Bus: Catch on-site? ☐ Y ☐ N ☐ Train: Catch on-site? ☐ Y ☐ N ☐ Bicycle	How many other people are travelling w/ you? ______	☐ On-Site: Name of Business/Building __________ ☐ Off-Site: Address/Nearest Intersection __________ City (if other) ______	☐ Walk: Walked all the way ? ☐ Y ☐ N ☐ Auto: Did you park? ☐ Y -On-site ☐ Y - Off-site ☐ N Did you pay for parking? ☐ Y ☐ N Did you get dropped off? ☐ Y ☐ N ☐ Bus: Did you get off at a stop on-site? ☐ Y ☐ N ☐ Train: Did you get off at a stop on-site? ☐ Y ☐ N ☐ Bicycle	How many other people travelled w/ you)? ______	What time did you arrive here? ___:___ ☐ AM ☐ PM	Home Zip Code: ______ Age: ____ Sex: ☐ M ☐ F	~Age? ____ Sex: ☐ M ☐ F
__:__ ☐ AM ☐ PM	☐ On-Site: Name of Business/Building __________ ☐ Off-Site: Address/Nearest Intersection __________ & City (if other) ______	☐ Walk: Will you walk all the way ? ☐ Y ☐ N ☐ Auto: ☐ Drive parked car ☐ Passenger in parked car ☐ Get picked up ☐ Bus: Catch on-site? ☐ Y ☐ N ☐ Train: Catch on-site? ☐ Y ☐ N ☐ Bicycle	How many other people are travelling w/ you? ______	☐ On-Site: Name of Business/Building __________ ☐ Off-Site: Address/Nearest Intersection __________ City (if other) ______	☐ Walk: Walked all the way ? ☐ Y ☐ N ☐ Auto: Did you park? ☐ Y -On-site ☐ Y - Off-site ☐ N Did you pay for parking? ☐ Y ☐ N Did you get dropped off? ☐ Y ☐ N ☐ Bus: Did you get off at a stop on-site? ☐ Y ☐ N ☐ Train: Did you get off at a stop on-site? ☐ Y ☐ N ☐ Bicycle	How many other people travelled w/ you)? ______	What time did you arrive here? ___:___ ☐ AM ☐ PM	Home Zip Code: ______ Age: ____ Sex: ☐ M ☐ F	~Age? ____ Sex: ☐ M ☐ F
__:__ ☐ AM ☐ PM	☐ On-Site: Name of Business/Building __________ ☐ Off-Site: Address/Nearest Intersection __________ & City (if other) ______	☐ Walk: Will you walk all the way ? ☐ Y ☐ N ☐ Auto: ☐ Drive parked car ☐ Passenger in parked car ☐ Get picked up ☐ Bus: Catch on-site? ☐ Y ☐ N ☐ Train: Catch on-site? ☐ Y ☐ N ☐ Bicycle	How many other people are travelling w/ you? ______	☐ On-Site: Name of Business/Building __________ ☐ Off-Site: Address/Nearest Intersection __________ City (if other) ______	☐ Walk: Walked all the way ? ☐ Y ☐ N ☐ Auto: Did you park? ☐ Y -On-site ☐ Y - Off-site ☐ N Did you pay for parking? ☐ Y ☐ N Did you get dropped off? ☐ Y ☐ N ☐ Bus: Did you get off at a stop on-site? ☐ Y ☐ N ☐ Train: Did you get off at a stop on-site? ☐ Y ☐ N ☐ Bicycle	How many other people travelled w/ you)? ______	What time did you arrive here? ___:___ ☐ AM ☐ PM	Home Zip Code: ______ Age: ____ Sex: ☐ M ☐ F	~Age? ____ Sex: ☐ M ☐ F
__:__ ☐ AM ☐ PM	☐ On-Site: Name of Business/Building __________ ☐ Off-Site: Address/Nearest Intersection __________ & City (if other) ______	☐ Walk: Will you walk all the way ? ☐ Y ☐ N ☐ Auto: ☐ Drive parked car ☐ Passenger in parked car ☐ Get picked up ☐ Bus: Catch on-site? ☐ Y ☐ N ☐ Train: Catch on-site? ☐ Y ☐ N ☐ Bicycle	How many other people are travelling w/ you? ______	☐ On-Site: Name of Business/Building __________ ☐ Off-Site: Address/Nearest Intersection __________ City (if other) ______	☐ Walk: Walked all the way ? ☐ Y ☐ N ☐ Auto: Did you park? ☐ Y -On-site ☐ Y - Off-site ☐ N Did you pay for parking? ☐ Y ☐ N Did you get dropped off? ☐ Y ☐ N ☐ Bus: Did you get off at a stop on-site? ☐ Y ☐ N ☐ Train: Did you get off at a stop on-site? ☐ Y ☐ N ☐ Bicycle	How many other people travelled w/ you)? ______	What time did you arrive here? ___:___ ☐ AM ☐ PM	Home Zip Code: ______ Age: ____ Sex: ☐ M ☐ F	~Age? ____ Sex: ☐ M ☐ F

APPENDIX D. INSTRUCTIONS FOR DATA COLLECTORS

Data collector training was critical for obtaining reliable data at field study locations. The following points were made during the pilot test and whenever new data collectors came to a site. These points were reiterated throughout the data collection process.

Key points made to door counters during training included:

- Understand the purpose of the study.
- Arrive at least 15 minutes before the start of the data collection period.
- Bring a watch or other device to keep track of 5-minute periods.
- Bring a pencil and something to write on.
- Concentrate and count every single person accurately. Door counts are the most critical piece of information being used in the study.
- Count every person entering and exiting the doorway. However, do not count people who take out garbage, take a smoke break in front of the building, or other people who obviously enter and exit without going to another activity location.
- Do not talk to others. Also avoid other distractions during the data collection period, such as using mobile devices (e.g., phone calls, text messages, Internet).
- Provide the one-page study information sheet to any person who asks them what they are doing; inform the data collection manager at the site if there are any problems with individuals.
- Show up on assigned data collection days. Even if the weather looks bad, assume that data will be collected until the data collection manager sends a cancellation notice. Data collection will be rescheduled on inclement weather days (i.e., ≥ 50% chance of rain predicted for the site at noon of the previous day on www.weather.com.)

Intercept surveyors were trained to:

- Understand the purpose of the study and the specific information solicited by the surveys.
- Arrive at least 15 minutes before the start of the data collection period.
- Bring at least 50 survey forms per surveyor (space for 200 potential surveys or refusals).
- Be confident when approaching people to interview (assume that they will agree to participate), but be polite when people decline to participate. Do not bother people who do not want to participate.
- Obtain the necessary information from respondents. This may involve modifying the language of the survey questions so that they are understandable to each respondent at each location (i.e., do not read the survey questions as a script).
- Ask all questions on the full survey and just the essential questions on an abbreviated survey.
- Do not lead respondents by guessing answers for them.
- Obtain the all travel modes used on each trip, including walking to and from parking or transit stops.
- Record the time at the beginning of the survey.
- Record responses and information about non-respondents completely.

- Do not spend more time interviewing participants of the opposite gender.
- Avoid socializing with respondents who may want to discuss topics that are not on the survey.
- Keep the most direct pathway to and from the door clear when inviting people to participate and when administering surveys.
- Do not disrupt normal business activity at the study location.
- Provide the one-page study information sheet to any person who has questions about the study; inform the data collection manager at the site if there are any problems with individuals.
- Show up on assigned data collection days. Even if the weather looks bad, assume that data will be collected until the data collection manager sends a cancellation notice. Data collection will be rescheduled on inclement weather days (i.e., ≥ 50% chance of rain predicted for the site at noon of the previous day on www.weather.com.)

APPENDIX E. FIELD DATA QUALITY CHECKS

At the end of each data collection period, managers reviewed the door counts and data collection sheets for unclear responses, errors, or other discrepancies. It was important to do this as soon as possible after data collection was completed because the data collector's memory was still fresh. This process did not catch every error, but it increased the accuracy of the counts and survey responses and helped the door count and survey personnel understand problems to avoid during the next data collection period. The review of data collection sheets was done most meticulously when data collectors were first starting to learn the data collection process.

This check examined the following information on count sheets:

- Data collector's name and specific count location were recorded on all sheets.
- The correct hour was written at the top of each sheet.
- The count covered the full data collection period.
- The balance of entry and exit counts looked reasonable for the time period observed.
- Variations by 5-minute period were logical.
- Total counts looked reasonable.

The following aspects of the survey forms were checked:

- Data collector's name and specific count location were recorded on all sheets.
- Time, estimated age, and estimated gender were recorded for survey refusals.
- Times of completed surveys were recorded.
- Write-in responses were complete and legible.
- All modes recorded for a specific trip were logical.
- Destinations for outbound trips recorded were logical.
- Origins for inbound trips recorded were logical.
- Times recorded for inbound trips were logical (e.g., if the time of the inbound trip was after the outbound trip, this would not make sense).
- Blank response items were noted. Surveyors were asked if they forgot to ask the question, if the participant didn't respond, or if they simply forgot to record the information on the sheet.

SMART GROWTH TRIP GENERATION DATA COLLECTION GUIDELINES

California Smart Growth Trip Generation Rates Study

University of California, Davis for the California Department of Transportation

March, 2013

AUTHORS
Robert Schneider, Ph.D., University of California, Davis
Kevan Shafizadeh, Ph.D., California State University, Sacramento
Benjamin Sperry, Ph.D., Texas Transportation Institute
Susan Handy, Ph.D., University of California, Davis

DISCLAIMER: The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California. This report does not constitute a standard, specification, or regulation.

1. INTRODUCTION

There is currently no commonly-accepted methodology in the U.S. to collect trip generation data and estimate trip-generation rates for land use projects in "smart growth" areas. Standard trip generation estimation methods established by the Institute of Transportation Engineers (ITE) are derived from data obtained mostly at suburban locations that lack good transit or pedestrian facilities (ITE Trip Generation Handbook 2004). The standard method is difficult, if not impossible, for practitioners to accurately estimate the actual transportation impacts of developments proposed in places where many different modes of travel are used. By following existing guidelines, transportation engineers often over-prescribe automobile infrastructure in smart-growth locations, resulting in wider roadways, more turning lanes, and more parking spaces than necessary. In addition, there is no established approach to recommend adequate pedestrian, bicycle, or public transit facilities that may improve conditions for traveling by these other modes.

The purpose of this report is to describe the data collection and analysis methodology used to document the number of pedestrian, bicycle, public transit, and automobile trips generated by developments in smart growth areas. This multimodal trip generation data collection and analysis approach was applied at 30 study locations in California. It is intended to be replicated and refined in other communities seeking to collect trip generation data in smart growth areas. This approach builds upon established methods so that it can be integrated easily into standard transportation engineering and planning practice. Ultimately, the results of this study and other smart-growth trip generation studies will benefit practitioners seeking to evaluate developments that support sustainable transportation and land use systems.

1.1. Definitions

There is no detailed, broadly-established definition of smart growth. However, in general, **smart-growth areas** are places where many common activities (e.g., workplaces, parks, coffee shops, stores, other homes) are located within a convenient walking distance of where many people live and work. Smart-growth areas are also typically served by pedestrian and bicycle facilities and frequent and reliable public transportation.

Places where activities take place are referred to here as **sites**, or developments. Sites may have a single type of land use activity (e.g., office building) or could include several different land use activities. Land use activities on a site are commonly called **uses**. Sites with more than one use are often referred to as **multi-use sites** (alternatively, "mixed-use developments"). These multi-use sites may be a single building with multiple uses (e.g., office building with restaurants on the ground floor) or several buildings with multiple uses on the same property (e.g., residential condominium building next to an office building).

Study locations for these guidelines should be located within a smart-growth area, and there are two types of possible smart-growth study locations. The first type of study location may have a single set of data collected for an entire, multi-use site. The second type of study location may have a **targeted land use** (e.g., mid- to high-density residential, office, retail, or coffee/donut shop use) within a larger site. One or more targeted land uses could be studied separately at a given site.

A **person trip** is defined here as the movement of one person between two activity locations. Travel from a person's previous activity location to one of the study locations is an **access trip**. Travel from one of the study locations to the person's next activity location is an **egress trip**. The sum of access and egress trips is the total number of trips generated at the study location. The **person trip generation rate** is the total number of trips generated at the study location during a one-hour period per square foot (for office and retail land uses) or per dwelling unit (for residential land uses). These guidelines further define the **afternoon peak hour person trip generation rate** as the highest rate for a one-hour period between 4 p.m. and 7 p.m. The **automobile trip generation rate** is the total number of automobile trips generated at the targeted activity location during a one-hour period per square foot (for office and retail land uses) or per dwelling unit (for residential land uses). If two people are traveling in the same automobile to a targeted activity location, they are making two person trips by automobile but only one automobile trip.

People often use more than one type, or mode, of transportation on trips between two activity locations. Modes may include walking a few blocks and then taking the bus for several miles or driving an automobile for several miles and then walking a few blocks. Bus stops, parking lots, or other places where people simply change modes are not defined as activity locations. As a result, the **primary trip mode** is defined as the mode used by a person for the longest distance on his or her trip between two activity locations.

2. GENERAL DATA COLLECTION APPROACH

The data collection approach was structured to be straightforward, easily replicated, and adaptable to any potential land use and smart growth development type. It builds on established ITE site-based trip generation data collection guidelines. This section provides an overview of the data collection timeframe and process used to derive multimodal trip counts. Additional details are provided in subsequent sections.

2.1. Study Timeframe

The study timeframe was chosen so that the trip generation data collected at smart growth study locations could be compared easily to standard trip generation data. Overall trip generation rates and modal trip generation splits at smart growth study locations may vary by the time-of-day, day of the week, season of the year. However, the timeframe selected for these guidelines match the most common time periods evaluated in practice. Established trip generation practices typically focus on weekday morning and afternoon commute travel periods, which often have the highest amount of traffic across the transportation system as a whole. It is important to recognize that travel to and from some specific land use types (e.g., schools, churches, restaurants) may peak at different times or on different days than the transportation system as a whole. Transportation system impacts at times other than weekday commute periods (e.g., mid-day or weekend peaks) may be an important topic for some studies, but these guidelines focus on overall peak periods rather than peaks specific to individual land uses. It is generally recommended that data be collected during the following periods:

- *Time of day*. Data should be collected during the peak travel periods from 7 a.m. to 10 p.m. and 4 p.m. to 7 p.m. The focus is on identifying the weekday peak hour, defined as the one-hour period with the highest automobile trip generation rate within each peak period.[1]
- *Day of the week*. Data should be collected on typical weekdays, including Tuesday, Wednesday, and Thursday.
- *Seasonality*. Data should be collected in the spring or fall seasons in most areas. Data collection should not occur during holiday periods or in the summer when schools are not in session.
- *Weather*: Aside from seasonal variation, data collection should be avoided on days with particularly cold or rainy weather, which could ultimately affect typical mode choice.

In general, data should be collected on typical commute days – when schools are in session and offices and business are operating normally. The data collection time periods should not represent any seasonal highs or lows at study locations.

2.2. Data Collection and Analysis Process

The data collection and analysis process should include the following four main components, described in greater detail below, for each peak hour studied:

1) Select study locations in smart-growth areas where trip generation data can be collected.
2) Collect data to quantify the total number of person trips generated and percent of person trips by mode for each study location.
3) Combine multimodal person trip data with vehicle occupancy information to estimate actual automobile trip generation rates.
4) Compare actual automobile trip generation rates to ITE automobile trip generation rates.

[1] Door counts are typically collected from 7 a.m. to 10 a.m. with the exception of commercial retail uses that do not open before 10 a.m. Intercept surveys are also collected from 7 a.m. to 10 a.m. at residential and coffee/donut shop study locations, and some trip information is gathered for the 7 a.m. to 10 a.m. period from 4 p.m. to 7 p.m. surveys at office study locations. The analysis may chose to avoid conducting intercept surveys in the morning period at an office study location because the intercept surveys are offered only as people exit doorways and because relatively few people exit offices in the morning. At some residential land uses, door counts can be collected from 6:30 a.m. to 10 a.m. to see if the morning peak hour is earlier than 7 a.m. to 8 a.m. Three-hour data collection periods are used rather than shorter periods to capture more intercept survey responses and create a better estimate of trip mode shares at targeted land uses.

Step 1. Select Study Locations in Smart Growth Areas
Identify appropriate land use category(ies) in the ITE *Trip Generation* report – Use of this method, the first step requires identifying the appropriate ITE-designated code for each land use on the site.

Step 2. Select Study Locations in Smart Growth Areas
In general, study locations with smart growth characteristics are found in urban areas with many activities located within walking distance and with good access to public transportation. Detailed guidelines for selecting the smart growth study locations are presented later in this report.

In general, there are two different approaches to data collection at study locations. Some study locations can be entire, multi-activity sites (i.e., trip generation is evaluated for the entire development of residential, retail, and office uses). Other study locations can be targeted land uses within a larger development (e.g., trip generation was evaluated for individual uses). The types of land uses targeted for the study are described later in the document.

Step 2. Collect Data to Quantify Total Person Trips Generated by Mode
A combination of door counts and intercept surveys are required to quantify the total number of person trips made to and from each study location by pedestrians, bicyclists, transit users, and automobile users during the peak hour. This information is combined with vehicle occupancy data to estimate an automobile trip generation rate in Step 3.

The combination of door counts and surveys is preferred over standard automobile tube counts for several reasons. Automobile tube counts at driveways and other site access points do not provide an accurate count of automobile trips, especially at smart growth study locations because 1) automobile users may park on the street or in an off-site parking lot and then walk to the study location and 2) people may park at a site but walk to a different location nearby without accessing a targeted land use, which is especially common at sites that have shared parking or general public parking. Automobile tube counts at driveways and other access points to a site do not capture trips made by other modes.

It is necessary to combine door counts and surveys to gather accurate multimodal trip generation data. The combination of data collection methods is preferred over using either method independently for several reasons:

- Simple door counts cannot determine whether each person's main mode of transportation is walking, bicycling, public transit, or automobile. Similarly, counting people at the boundary of a development cannot identify whether a pedestrian is walking as their primary mode, walking to or from a parked car, or walking to or from transit (Pike 2011). Intercept surveys gather detailed travel characteristics from respondents so that their primary trip modes can be determined accurately.
- It is difficult and impractical to survey all people exiting a building. Therefore, door counts are necessary to quantify the total number of person trips generated by each

targeted land use. These counts are then used to extrapolate the intercept survey data to represent the total number of person trips by mode at each targeted land use.

Step 3. Estimate Actual Automobile Trip Generation Rates
The multimodal person counts and intercept surveys are used to estimate automobile trip generation rates. Door counts provide the total number of person trips to and from the study location during the peak hour. The intercept survey shows the proportion of all trips that are made by automobile as well as automobile occupancy. The total number of person trips is multiplied by the proportion of trips by automobile to derive automobile person trips. These automobile person trips are then divided by the average automobile occupancy at each site to calculate the total number of motor vehicle trips generated at each study location during the peak hour.

Step 4. Compare Actual Automobile Trip Generation Rates with ITE Rates
The previous step provided an estimate of the actual afternoon peak hour automobile trip generation rates at each study location. ITE peak hour automobile trip generation rates are derived from study location characteristics (e.g., number of residential units, number of gross square feet of office space) using the ITE Trip Generation Manual (2008). The difference between the actual automobile trip generation rates and ITE rates will be the focus of further analysis.

These guidelines are based on ITE data collection guidelines for trip generation studies[2]. Basic ITE requirements should be followed, though some aspects can be modified to capture data efficiently and accurately at study locations with smart-growth characteristics. The only ITE site selection guideline that is not considered in the criteria for selecting study locations in these guidelines is the recommendation to count at isolated sites and discourage counting at study locations where pedestrian and transit access are common. Since the purpose of this effort is to gather data at smart growth sites and collect data on different modes, the count and intercept survey guidelines have been designed to capture these modes accurately[3].

3. SMART GROWTH SELECTION CRITERIA AND STUDY LOCATION CHARACTERISTICS

The analysis focuses on trip generation data at study locations in smart growth areas. Three principles guide study location selection process.

1) Study locations should meet objectively-defined smart growth criteria and include at least one specific land use targeted by this study.
2) Study locations should have similar characteristics to other locations where trip generation analyses are applied.

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[2] Institute of Transportation Engineers. *Trip Generation Handbook: An ITE Recommended Practice*, Second Edition, Principal Editor: Hooper, K.G., June 2004.
[3] Site selection guidelines are on pp. 17-18 of the ITE *Trip Generation Handbook: An ITE Recommended Practice* (2004).

3) Study locations must be practical for conducting intercept surveys and cordon counts.

The guidelines in the following sections helped identify study locations.

3.1. Smart Growth Characteristics

The smart-growth guidelines in this subsection provide more specific information related to the four smart-growth principles described in "Evaluation of the Operation and Accuracy of Five Available Smart Growth Trip Generation Methodologies"[4] and include characteristics commonly used as smart-growth measures by the State of California[5] and other organizations[6,7]. Since there are no detailed, broadly-established smart-growth standards, the smart-growth guidelines used for this project were established collaboratively by the project Research Team and a Practitioners Panel. The following criteria were used to selected study locations in California:

- Location: The area within 0.5 miles of the study location should be mostly developed[8]. The study location should not be on the periphery of an urban area.
- Land Use Mix: There should be a mix of land uses in the area within 0.25 miles of the study location. In general, single-use zoning is not consistent with smart growth principles.
- Jobs/Housing Density: There should be at least 6,000 residents living within 0.5 miles of the study location (7,639 residents/mi^2) or at least 1,000 jobs within 0.5 miles of the study location (1,273 jobs/mi^2)[9]. These values provide a rough measure to ensure that the study location is close to a sufficient number of people and activities.
- Transit Accessibility: The study location should be served by frequent transit service. This includes bus stops for at least two routes within one block of the study location that have 15 minute or shorter bus peak period headways or a rail station within 0.5 miles that has 20 minute or shorter peak period rail transit headways[10]. Ferry terminals should not be considered.
- Bicycle Accessibility: The study location should have bicycle lanes, multi-use pathways,

[4] Lee, R., J. Miller, R. Maiss, M.M. Campbell, K.R. Shafizadeh, D.A. Niemeier, S.L. Handy, and T. Parker. *Evaluation of the Operation and Accuracy of Five Available Smart Growth Trip Generation Methodologies*. Appendix B, Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-11-12, 2011.

[5] California Senate Bill 375, 2008. Section 13 defines "infill site," and Section 14 defines "transit priority project."

[6] US Green Building Council. *A Citizen's Guide to LEED for Neighborhood Development: How to Tell if Development is Smart and Green*, Available online: http://www.nrdc.org/cities/smartgrowth/files/citizens_guide_LEED-ND.pdf, 2011.

[7] Washington Smart Growth Alliance. *Smart and Sustainable Growth Recognition Criteria*, Available online: http://www.sgalliance.org/documents/SGRPCriteriaOnly.9-1-2010.pdf, 2010.

[8] Smart growth criteria that use area measurements can be calculated from simple buffers at specified distances from the center of the study location.

[9] 7,639 residents/mi^2 is equivalent to 4.59 dwelling units per gross acre, assuming the national average of 2.6 residents per household.

[10] Smart growth criteria that use proximity to specific transportation facilities (measured in numbers of blocks) can be measured from the boundary of a multi-use site or from the doors of a targeted land use.

or other designated bicycle facilities within two blocks[11].

- Pedestrian Accessibility: There should be more than 50% sidewalk coverage on streets within 0.25 miles of the study location (100% sidewalk coverage is sidewalks on both sides of all streets; 50% sidewalk coverage is a sidewalk on one side of all streets or sidewalks on both sides of half of streets).

Note that some study locations chosen for study may not meet every single guideline. The guidelines were treated with enough flexibility to identify a sufficient sample of study locations for analysis, and these guidelines should not be viewed as rigid constraints that preclude a study location that meets nearly all of the criteria but does not quite meet the minimum or maximum threshold for a few characteristics.

3.2. Study Location Characteristics for Transferrable Results

Study locations should be comparable to other similar developments throughout California and the United States, which would make it easier to integrate the results of the project with existing trip generation analysis practices. The following guidelines have been established to make the results more transferrable to other locations:

- The study location should contain at least one of the following land uses:
  - Mid-to-high density residential, including high-rise apartment (ITE land use code 222), mid-rise apartment (223), or high-rise residential condominium/townhouse (232) (developments that contain more than 50% subsidized, low-income residential units should be excluded).
  - Office, including general office building (710).
  - Retail, including specialty retail (814), pharmacy/drugstore without drive-through window (880), or shopping center (820).
  - Coffee/donut shop without drive-through window (936).[12]
- The land use mix within and surrounding the study location should be similar to other developments (i.e., it is not so unique that the trip generation data would not apply to other sites). For example, the following study locations should probably be avoided:
  - Specific land uses with higher-than-normal overall customer bases, such as the only grocery store in an entire downtown district.
  - Study locations in university areas. This includes study locations within 1.0 miles of a university with 5,000 or more students and study locations within 0.5 miles of census tracts with more than 15% of the population between ages 18 and 21.
  - Study locations that include or are located within 0.5 miles of stadiums, military bases, commercial airports, major tourist attractions, "specialty" shopping areas (e.g., Union Square in San Francisco), subsidized housing projects, or other special attractors that are not typically included in trip generation studies.
- There should be no construction or other activity at or near a study location that

[11] To be counted as "designated bicycle facilities," the facilities should include more than standard bicycle route signs or pavement markings that direct drivers and bicyclists to share existing travel lanes.

[12] The targeted land uses can be limited to these specific land use codes in order to have a manageable number of land use codes to study.

restricts access and activity volume.

- The site or targeted land use should be at least 80% occupied and at least two years old. As a rule of thumb, retail and residential developers generally look to achieve 90% occupancy. Below 75% occupancy is considered a failed retail development. Office developers look for 85% occupancy.

3.3. Study Location Features for Efficient Data Collection

It is important for study locations to be practical for conducting door counts and intercept surveys. The following guidelines help to identify study locations for efficient data collection:

- Permission should be obtained from the property owner/manager to collect data at each site or targeted use[13]. Even if a study location has ideal smart growth characteristics and land use types, it may not be possible to collect data because the property owner will not grant permission. In most cases, the property owner or manager communicates with internal businesses, residents, and other tenants about permission for the study. In some cases, the survey supervisor may need to make direct contact with individual owners to gain full permission. Therefore, study locations under ownership or management of one entity are preferred over locations with multiple owners or managers due to the complexity of obtaining permission to collect data.
- The study location should have a definable external boundary that can be used for cordon counts, which may include a site (property) boundary, a building perimeter, the set of doorways used to enter and exit a targeted land use, or an arbitrary cordon line that will be readily comprehensible and easily remembered by survey personnel.
- Multi-use buildings should have definable internal boundaries (e.g., doors where counts can be taken) between different targeted land uses. For example, in a mixed-use office building with a restaurant on the ground floor, data should be collected at internal doors that connect the restaurant to the office space (as well as other external doors to both uses). If ground-floor retail or restaurant units have no internal connection to other uses within the building, they can be evaluated independently.
- To conserve data collection resources, the study location should have a limited number of doorways. In general, one door counter and one intercept surveyor is needed at each door. Yet, it is possible to increase the coverage of each data collector at certain types of study locations.
    - o At some study locations, a single door counter can observe two or three different

[13] Obtaining permission to collect data at specific sites or targeted uses is essential to implementing the door count and intercept survey methodology. The survey supervisor should contact property management by phone and e-mail, and then meet as necessary to discuss the purpose and procedures of the data collection effort. During each contact, the survey supervisor should emphasize that the data collection team 1) will be professional, 2) will not impede or hassle tenants or customers (any person who refuses to participate in the intercept survey will be left alone), and 3) will not divulge proprietary or sensitive information. An incentive for property management to cooperate may be to offer the opportunity to receive the survey results or a copy of the study report. In some cases, when permission is first requested, the initial contact person may not allow data collection. However, follow-up calls or visits with the initial contact or someone at a higher management level (e.g., corporate headquarters) may help ease concerns and secure permission. In other cases, the first contact person may initially provide permission, but their boss or corporate management may later rescind permission. It is can a challenge to obtain permission.

doors simultaneously from a carefully-selected vantage point. This approach works best at locations with relatively low levels of activity.

  - It may be possible for a single intercept surveyor to cover more than one doorway at the same time. This approach is possible when doors are no more than 20 to 30 feet apart.
  - It may be possible for a single intercept surveyor to rotate among several doors, spending specific time intervals at each door so that the probability of intercepting an individual from each door over the entire data collection period is roughly equal.
  - In undesirable cases where certain doors are counted but not surveyed, it is possible to extrapolate survey responses from a carefully-chosen sample of other similar doors at these sites. However, as the percentage of surveyed doors becomes smaller, extrapolation estimates become less accurate.
- The study location should not have significant through traffic. If there are people who pass through the building doors without accessing a targeted land use on the site (e.g., people who use public parking in a building before walking to another building or people who access a different use in the building that is not being studied), these trips should be identified through intercept surveys. These trips should be excluded from the analysis.
- A study location should have enough activity to provide a sufficient number of intercept survey interviews during a single day of data collection. A goal should be to record at least 50 trips (absolute minimum of 30 trips) during each afternoon peak period at each study location. Sample sizes of less than 30 are typically avoided to ensure the sample results benefit from the central limit theorem that says the sampling distribution of the means will approach that of a normal distribution even if the population being sampled is not normally distributed.[14] As a rule of thumb, residential sites with fewer than 150 units and offices with less than 100,000 gross square feet may not to have enough activity.

3.4. Field Visits to Finalize Study Locations

Field visits should be made to the study locations before the day of data collection. Field visits should be conducted to:

- Select specific buildings and uses within buildings to be targeted for data collection.
- Observe activity patterns within and around the study location and anticipate how activity patterns may change between morning and evening peak periods (based on observed movements and land use types).
- Observe how people travel to and from transit stops, parking lots, and parking garages to access the study location.
- Note whether parking lots and garages allow public parking, which may suggest that people use an on-site parking lot but do not go to any of the targeted land uses on the site.
- Estimate the total number of data collectors needed to do door counts and intercept

[14] *Fundamental Research Statistics for the Behavioral Sciences*, John T. Roscoe, Holt, Rinehart and Winston, Inc., 1969.

surveys at each study location (e.g., identify any locations where a single counter or surveyor could cover more than one door or any low-activity doors where surveyors may not be needed).

- Identify where data collectors should stand outside of all doors at each study location during morning and evening periods.
- Anticipate potential challenges to data collection.
- Record data on explanatory variables that can only be collected in person.

Google Street View can be used to review site characteristics at study locations before data are collected. This approach works but is not ideal, because on-line image sources like Google Street View may not always have up-to-date pictures, may not always indicate whether parking garages allow public parking, may not show internal building doorways between uses, and may not provide a good sense of specific activity patterns or overall levels of activity at study locations.

3.5. Characteristics of Study Locations

Some targeted land use study locations shared the same building, site, and surrounding area characteristics. Summary statistics describing the characteristics of the entire set of study locations should be interpreted with this in mind.

The study locations represented smart-growth areas in the urban areas. A variety of development types can be represented, including:

- Central business districts
- High-density residential developments within urban areas
- Office developments within urban areas
- Commercial retail developments within urban areas
- Mixed-use developments within urban areas
- Transit-oriented developments

3.6. Site Layouts

Development sites in smart growth areas often have multi-use buildings with internal doorways, multi-story parking garages, parking lots shared among several nearby land uses, and a mix of public and private parking. These site layout characteristics are critical to understand in order to obtain an accurate count of the trips generated by each mode at each study location. Different layouts required different approaches to data collection. Common site layouts observed at the study locations are described below.

Type 1. Multi-Building Site

Multi-building sites have one trip generation rate calculated for a single property with several different buildings. Data collection at these sites involves counts and surveys at each access point on the boundary of the site. These access points includes driveways, external building doorways, and parking garage entrances and exits.

Type 2. Targeted Use with No Parking Lot

Some targeted land uses do not have a direct connection to a parking lot. These targeted uses are typically in urban core areas with high-density residential or commercial development. Data collection at these study locations involves doing counts and surveys at the doors to the targeted use. Unless there is a transit stop within the site containing the targeted use, all people who travel to this type of study location should be recorded as walking for at least part of their access or egress trip (although walking should only be considered the primary trip mode if the person walked for the entire trip distance).

Type 3. Targeted Use with Private Parking Lot

Other targeted uses may be served by their own private parking lot, which could be a surface parking lot or a parking garage. Where possible, data should collected at all doorway access points to the targeted use (including access points from different levels of a multi-story parking garage). However, if the property manager does not provide permission to survey inside the parking garage or at other locations on private property, data collectors may stand at direct public access points to the targeted use and public access points to the parking lot. Respondents who park in the private parking lot should be considered to be using an automobile to access the targeted use. They should not be recorded as walking for the part of their trip between their parked car and the doorway.

Type 4. Targeted Use within Site with Shared Parking

A few targeted uses may be part of larger sites that share parking between uses or provide public parking, which could be a surface parking lot or a parking garage. Where possible, data should be collected at doorway access points to the targeted use. However, if the property manager does not provide permission to survey inside the parking garage or at other locations on private property, data collectors can stand at direct public access points to the targeted use and public access points to the parking lot. In most cases, respondents who park in the parking lot at this type of study location should considered to be using an automobile to access the targeted use, regardless of where they park on the site. However, if a respondent parks in the parking lot and visited a different use on the site before he or she went to the targeted use, he or she can be recorded as walking to the targeted use. The same rule can be applied in reverse for the egress trip from the targeted use. People who accessed the parking lot or a different use on the site but did not access the targeted use should not be counted in the analysis phase of the study.

Type 5. Targeted Use in Multi-Use Building with Internal Connections

In some cases, the targeted use can be connected to other uses in the same building through internal doorways. Data collection at these study locations involved doing counts and surveys at the doors to the targeted use. This included internal building doorways connecting from other uses to the targeted use. If a respondent traveled between the targeted use and another use in the building through an internal doorway, he or she should be recorded as walking for this trip. It is possible for multi-use buildings to have no parking, private parking, or shared parking.

4. FIELD DATA COLLECTION

Field data collection requires a combination of door counts and intercept surveys. These two aspects of the trip generation data collection process are described in detail below. The final parts of this section describes the data collector training process, field work, and data entry.

4.1. Door Counts

The core field data collection component at each study location is a count of all people entering and exiting the site or targeted land use. This count provides the total number of person trips generated at each study location during the afternoon peak period.

Door counters should tally all people passing through the doorways (except people who take out garbage, take a smoke break near the building, or other people who obviously enter and exit without going to another activity location). People entering each door are counted separately from people exiting. Gender can also be recorded to help identify if either gender is underrepresented in the intercept survey. Gender bias can be corrected later by weighting the survey results based on observed door counts. Finally, the door counts are tallied in five-minute increments, which makes it possible to identify trip generation peak patterns within shorter time intervals (e.g., the afternoon peak hour can be identified as being 4:25 p.m. to 5:24 p.m. rather than 4:30 p.m. to 5:29 p.m.). The door count form is provided in Appendix A.

Staffing requirements and data collector positioning must be identified in advance of the data collection period at each study site. Slightly different strategies may be used to gather accurate counts at sites with different layouts:

- At multi-building sites, counts should be taken at all access points on the boundary of the site. These site boundary counts include all people entering and exiting the site. People traveling together in the same automobile should be counted individually.
- At most targeted land uses, counts should be taken at all doorways providing access to that use, including internal doorways connecting the targeted use to the parking garage or other uses within a building.
- At several targeted land uses, it may not be possible to count people at doorways leading directly to the targeted use, which may occur at multi-use buildings where permission is not provided to count at internal locations within the building, such as at doors leading from a parking garage directly to the targeted land use. In these study locations, counts can be taken at external doorways, such as parking garage entrances and exits. However, these counts should include people going to or coming from any use in the building (or other nearby locations if the garage is public), not just people who access the targeted use. Therefore, survey respondents intercepted at the external doorways should be asked to indicate whether or not they actually visited the targeted use, and this information should be used to adjust the count data to reflect the number of trips to and from the targeted use.
- At study locations where transit stops are located within the site or targeted use, it would be necessary to count all passengers as they boarded or exited the bus or train.

However, for comparison to standard automobile tube counts, buses would also need to be counted as single vehicles.

The total count of person trips at each door can be allocated by travel mode using intercept survey data collected at that door. It may not possible to obtain complete surveys from every person entering and exiting a study location, so the door counts are critical to providing the best-possible estimate of the correct trip generation rate.

4.2. Intercept Surveys

In-person intercept surveys should be offered to a sample of people as they exit doors at each study location. These surveys have been designed to determine: 1) the mode, time of day, origin, and length of access trips to the study location and 2) the mode, time of day, destination, and length of egress trips from the study location. The travel mode and time of day for each trip are the most important pieces of information on the survey because they are used to allocate the peak-hour door counts by travel mode. The intercept surveys also collect information about vehicle occupancy so that the person trip counts for automobile users can be compared to ITE vehicle-based trip rates.

Age, gender, and home zip code are included on the survey to identify socioeconomic characteristics of participants. Comparing the gender of survey respondents to the gender of people counted at doors makes it possible to account for any potential gender bias in the sampling procedure. Trip origins and destinations, trip length, respondent age, and respondent zip code are all optional and can all be used for additional travel behavior analysis. Finally, the survey form also includes space for data collectors to note the time of survey refusals as well as estimates of the gender and approximate age of individuals who refused to participate. The standard survey form is shown in Appendix B. There is space for up to five different respondents to provide access and egress trip information on a single page.

The full survey typically takes 30 to 60 seconds for respondents to complete. If a respondent makes multiple trips to and from the study location during peak hour travel periods that day, the survey can take slightly longer than 60 seconds.

Some potential respondents can be in a hurry as they exit study locations, so they may not want to stop to complete the full survey. Some of these people refuse to participate. However, some of them may be willing to share information quickly as they walk by. An abbreviated version of the survey can be used in this situation. This abbreviated version asks only two questions about the respondent's current trip: "How are you getting there?" and "Where are you going?" This option can be completed in around 10 to 15 seconds. The mode of transportation for the respondent's current trip remains the only absolutely essential information needed to constitute a usable survey for the purpose of this study. Therefore, partial survey responses still provide useful information, even though they may not include many details.

Exit surveys are used rather than entry surveys for several reasons. Survey participants can be selected randomly. Surveyors did not have an option to choose people who they thought would be more likely to participate in the survey; they should be trained to always invite the next person who exits the door. Furthermore, entry surveys have several disadvantages. It is more difficult to get permission for surveyors to stand inside the building and intercept people as they entered doorways. If the surveyors stand outside (typically on public property or in a common area), it can be difficult to determine which people are going to the targeted use and which people are just walking by. In addition, at locations where surveys are offered at parking garage access points, it can be onerous for drivers to stop while entering from the street. It is much easier to stop drivers at an exit as they approached the public sidewalk crossing.

During the survey, respondents are asked where they are going (egress trip) before they are asked where they came from (access trip) for three reasons:

1. Respondents are expected to be able to answer the question easily. They would be aware of where they are going at the time of the survey and would not need to try to recall a trip made earlier in the day.
2. The mode of the current trip is the only absolutely essential piece of information that is required from a respondent, so this survey design makes it possible to obtain that information in the first question. In many cases, hurried respondents may also able to respond with the name of the intersection closest to where they were going next before walking, bicycling, or driving away. These abbreviated surveys are still useful for the main purpose of the research project.
3. Asking about travel mode first helps to engage respondents. By quickly asking, “What type of transportation are you using now?” or using the modified wording, “Can you tell me about your commute home?” or “Can you tell me about your travel for 15 seconds for a Caltrans study?”, the surveyors are able to generate immediate interest in the survey.

In practice, when the full survey is used, the order of the survey questions can be somewhat confusing for the survey personnel and respondents. It may be easier to ask questions chronologically, starting with where the person came from immediately before accessing the study location and the mode they used to make that trip. Then the current trip mode and destination can be investigated. However, the abbreviated survey only asks about the current trip, so it makes sense to have this information listed first.

Surveyors will learn to adapt the language and order of the survey questions to obtain the information needed. Depending on the site layout, characteristics of the exit point, and the type of targeted land use where surveys are being offered, the survey can progress more smoothly when the surveyor put questions into his or her own words. Therefore, initial training and practice is critical to make sure surveyors understand the type of information that should be recorded and to let them know that they have the flexibility to modify and diverge from the survey script when necessary. The survey form can be adapted for respondents to provide information about multiple trips to and from the study location (more than a single access and a single egress trip).

Surveyors and door counters should be stationed at parking garage access points at some study locations. This approach can be used at buildings where property management does not allow data collection in the parking garage or other locations inside the building. These parking garages often serve multiple uses (not just the targeted use). Therefore, the surveys are essential for determining the proportion of people exiting that actually accessed the targeted use.

Parking garage entrance surveys use a slightly modified approach. Intercept surveyors wearing orange and yellow vests stand on the driver's side of the garage exit point (at or just in advance of where the garage driveway crosses the public sidewalk). When a vehicle approaches, they can motion to drivers to roll down their window and take the abbreviated version of the survey. The mode question is straightforward (automobile), so the only other critical survey information is whether or not the respondent actually visited the targeted use. Many drivers may stop long enough to provide their trip destination and home zip code. The total number of people in the automobile can be observed. These parking garage surveys take less than 15 seconds. To prevent congestion and driver frustration, surveyors did not ask drivers to stop for the survey if there are other vehicles immediately behind approaching the garage exit.
Future applications of the survey methodology can test different orders of questions and different types of survey forms. The ideal survey form should be adaptable to full-length or abbreviated surveys and be easy to understand in either case. Other suggestions for future multimodal trip generation intercept surveys include:

- Provide in-depth training to surveyors. Focus on understanding the definition of an access trip and an egress trip (some surveyors interpreted the "trip you took to get here" as the 10- to 20-foot movement from the door of the study location to the surveyor—rather than the trip they had taken to get to the study location).
- During training, clarify that surveyors should not try to guess the mode of transportation people are using if they refuse to participate in the survey. To be participant in the survey, a person must at least give a verbal answer to the type of transportation that he or she is using on his or her current trip. Otherwise, they should be marked as a refusal. Surveyors should not try to guess the mode being used, even if they are able to watch a person who refused the survey walk the whole way to his or her next activity or get on the bus at an adjacent bus stop. Even though the surveyor could record the mode used in the examples above "correctly," those trips would not be sampled in the same way as trips from other respondents which is a problem because there is no way to correctly guess the mode of a person who walks to parking or walks to a transit stop that is out of sight. If non-respondents whose mode could be observed "correctly" are included, the

modes that could be observed directly would be oversampled, which would introduce bias into the results.

- Add a short question to the survey to determine whether or not the person actually accessed the targeted use. This is needed at doorways that may be used by people from other uses in the building or surrounding area besides the targeted use.
- Surveyors should use the time in between surveys to make sure their handwriting is clear, spell out abbreviations, and clarify any markings or notes that could help make data entry easier. This is especially important because someone other than the data collector often enters the data.
- Data collection managers should review survey responses recorded over the first 30 minutes of a data collection period to correct any systematic errors being made by the surveyors. At sites with morning surveys and afternoon surveys, data collection managers should review the morning surveys to catch common errors and discuss them with the surveyors before they start afternoon data collection.
- Try to get permission to survey at doors that provide direct access to targeted land uses rather than at shared parking garage entrances. Surveying all people exiting parking garages just to obtain data from a certain proportion of people who accessed a particular use on a site is less efficient (surveyor time is spent collecting non-usable survey data) than surveying at direct access points. It also introduces another analysis step and its associated error into the final trip generation calculations. When the methodology is used in the future, data collection managers may want to make a rule that targeted uses should not be studied unless the property manager provides full permission to survey at all direct access points to the targeted use.

4.3. Recruitment and Training

This method requires reliable door counters and intercept surveyors. Professional data collection companies can be used to conduct intercept surveys, while temporary agency personnel can be hired to conduct counts at doorways. After recruiting professional data collection companies, the survey processes must be discussed and coordinated with managers at these companies. The intercept surveyors require an outgoing personality. The interviewers provided by the data collection companies should be friendly, assertive, willing to approach and talk to strangers, look professional, and understand the purpose and procedure for the interviews. Key points made to door counters and intercept surveyors during the data collection process are listed in Appendix C.

4.4. Data Collection at Study Locations

Several days in advance of field data collection at each study location, a map should be prepared of the study locations where door counts and intercept surveys are conducted. Maps also included the names of buildings, stores, and areas to which survey respondents could refer.

On data collection days, door counters and intercept surveyors should be oriented around the site at least 15 minutes prior to the beginning of the data collection period. Early arrival allows data collectors to observe the site layout, familiarize themselves with their particular survey or count location, and use the restroom, if necessary. Prior to the start of a data collection period, the data collection manager can review the data collection procedure with each data collector and answer any questions. The data collection manager can also confirm that counters know which movements should be noted and where the counts should be recorded on the form. After data collection begins, the supervisor should circulate among the counters and surveyors in the field to ensure data are being collected correctly. (See Appendix D).

The data collection managers should monitor the real-time progress of the counts and intercept surveys and made adjustments as necessary to achieve a sufficient sample. Adjustments can include redeploying surveyors to different locations with more activity. If there are extra personnel, they can be rotated among the doorways where counts or surveys are being taken to give short breaks to other data collectors. If extra data collectors are not available, the data collection manager can step in to provide relief to the data collectors.

4.5. Data Entry and Quality Control

The paper door count and intercept forms are entered into electronic spreadsheets. Data entry is a time-consuming process, and quality control checks are important part of the process. Count forms and intercept forms should be systematically checked with the database for errors or mistakes.

5. DATA PROCESSING AND ANALYSIS

This section describes how the count and survey data are analyzed to estimate trips to and from each study location during the afternoon peak hour. This process involves several steps:

- Step 1. Quantify the total number of person trips made during the afternoon peak hour to and from each study location.
- Step 2. Determine the trip mode share at each door during the three-hour afternoon data collection period.
- Step 3. Allocate peak-hour person trips by mode at each door.

1. Step 4. Calculate peak-hour person trips by mode for the full study location.

5.1. Quantify Total Peak-Hour Person Trips at the Study Location

People should be counted entering and exiting doors over five-minute intervals throughout the three-hour study period at each study location. These door counts should be summed to quantify the total number of person trips generated by the targeted land use. At some sites, counts can be taken at doors to a garage that allowed public parking. In these locations, a portion of the people counted at the garage doors may not access the targeted land use (e.g., they may access another land use within the building, access another land use nearby, or just pass through the garage). Survey responses are used to identify and subtract the people who do not access the targeted use at each door. Next, the number of peak-hour person trips is quantified at each study location.

5.2. Determine Trip Mode Share at Each Door

To estimate the travel modes used for peak-hour person trips, the modes used by intercept survey respondents at each individual door at a study location should be determined. Surveys capture information about the mode of transportation used by a sample of people exiting doorways from each study location. The respondents report all modes that they used on each trip, including any walking done between an off-site parking space or transit stop and the study location. For all usable surveys, the primary trip mode can be assigned based on the following assumptions:

- If a respondent uses transit on any part of his or her trip, transit is likely the primary trip mode. People may drive, walk, or bicycle to or from transit, but if they use transit, they often take it for the longest distance on their trip.
- If a respondent did not use transit but used automobile on any part of his or her trip, automobile is likely the primary trip mode. People may walk to or from automobile parking, but if they use an automobile, they often use it for the longest distance on their trip.
- If a respondent did not use transit or automobile but used a bicycle on any part of his or her trip, bicycle is likely the primary trip mode. People may walk to or from bicycle parking, but if they use a bicycle, they often use it for the longest distance on their trip.
- If a respondent walked the whole way on his or her trip, walking is the primary mode.

Individual doors should be analyzed because certain doorways may have different mode shares than the overall study location (e.g., a door leading to the parking lot may have more automobile users; a door leading to a bus stop may have more transit users). It is necessary to account for these differences to calculate the overall study location mode share correctly.

The mode share at each doorway is calculated from primary trip mode data collected over the full three-hour afternoon survey period, which is done to increase the number of sampled trips used to calculate mode share. It is possible that trip mode share at a particular door could change within the three-hour study period due to different activity patterns and transportation system characteristics (e.g., peak transit service frequency, traffic congestion, variable parking pricing), but it is assumed to be constant for the purposes of this type of study

Low-activity doorways at sites with multiple doorways should be counted but may not be surveyed. In these cases, person trips in and out of these doors are counted, but the modes used for these trips should be assigned based on other similar doorways at the study location. Mode shares from similar doors are used rather than an average of all doors because it is likely to provide a better estimate of the actual mode share at a particular door. For example, parking garage doors are likely to have a similar mode shares (a high proportion of automobile trips); doors leading to nearby transit stops are likely to have similar mode shares (a high proportion of transit trips).

During this step, survey respondent gender is compared with the count of females and males at each door. If the proportion of survey respondent trips from one gender is lower than the other, the trips reported by respondents of that gender are given a higher weight in the final mode share calculation. This step should remove any gender bias from the surveys. Removing gender bias is important, because travel surveys have shown differences in mode share by gender, particularly for bicycling (Cervero and Duncan 2003; Schneider 2011).

5.3. Allocate Peak-Hour Person Trips by Mode at Each Door

The next step requires allocating the peak-hour door count trips by mode. The peak-hour trip numbers are calculated from the door counts in Step 1, and the mode shares are estimated from the survey data in Step 2.

5.4. Calculate Peak-Hour Person Trips by Mode at the Study Location

Finally, the trips made in and out of each door by each mode are summed to derive peak-hour person trips by mode for the overall study location. Note that this method of summing trips by door gives the appropriate weight to doors with different activity levels. Peak hour person trips can be estimated for pedestrian, bicycle, public transit, and automobile modes.

5.5. Compare Peak-Hour Vehicle Trips by Study Location with ITE Estimates

To compare trips generated at study sites with existing ITE trip generation methods, it is necessary to convert the afternoon peak hour automobile person trips to afternoon peak hour vehicle trips using automobile occupancy information from the surveys. The overall automobile occupancy at a site is simply the average occupancy for all reported automobile trips to and from the site. Afternoon peak hour vehicle trips are the peak hour automobile person trips divided by the overall automobile occupancy at the site. The observed trips can then be compared to the number of afternoon peak hour trips estimated by standard ITE trip generation methods (ITE 2008).

6. CONCLUSIONS

Many communities are encouraging development in urban areas so that they can grow more sustainably and provide more transportation options for residents and visitors. To better evaluate transportation impacts of these types of developments, there is a need to collect new, multimodal trip generation data in smart growth areas. The methodology described in this report can be used by other researchers and practitioners to modify existing suburban-based trip generation rates. This approach can be used to gather consistent data that can be compared across study sites in California and throughout the United States. Ultimately, a national multimodal trip generation database could provide the foundation for new, multimodal trip generation rates for a variety of land uses in smart growth areas.

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APPENDICES

A. Standard Door Count Form
B. Standard Intercept Survey Form
C. Instructions for Data Collectors
D. Field Data Quality Checks

APPENDIX A. STANDARD DOOR COUNT FORM

Door Count Form
(Use one sheet each hour. Write start time at top of each sheet.)

Site: ___________________________________ Name: ________________________________ Date: ___________

Time [Start ____:____ am/pm]	Direction	Location:____________		Location:____________		Location:____________	
		Male	Female	Male	Female	Male	Female
:00 to :04	In						
	Out						
:05 to :09	In						
	Out						
:10 to :14	In						
	Out						
:15 to :19	In						
	Out						
:20 to :24	In						
	Out						
:25 to :29	In						
	Out						
:30 to :34	In						
	Out						
:35 to :39	In						
	Out						
:40 to :44	In						
	Out						
:45 to :49	In						
	Out						
:50 to :54	In						
	Out						
:55 to :59	In						
	Out						

APPENDIX B. STANDARD INTERCEPT SURVEY FORM

Exit Intercept Survey: As persons DEPART, intercept as they leave a specific entrance.

Interviewer Name:______________ Cell Phone: (____)__________ Building: ______________ Date: ___________ Start Time: ____:____ am pm Page _____ of _____

"Hello! Do you a have a minute to take a brief transportation survey?" (This survey is for a research project led by UC Davis for the California Department of Transportation. Feel free to decline to answer any questions you are not comfortable with.)

Time of Survey	Where are you headed now? (Check one only.)	How will you travel to get there? (Check each that applies.)		Where did you come from immediately before you came here? (Check one only.)	How did you travel here? (Check each that applies.)			Other Info (Ask all.)	Refusal?
___:___ ☐ AM ☐ PM	☐ **On-Site**: Name of Business/Building __________ ☐ **Off-Site**: Address/Nearest Intersection __________ & City (if other) ________	☐ **Walk**: Will you walk all the way ? ☐ Y ☐ N ☐ **Auto**: ☐ Drive parked car ☐ Passenger in parked car ☐ Get picked up ☐ **Bus**: Catch on-site? ☐ Y ☐ N ☐ **Train**: Catch on-site? ☐ Y ☐ N ☐ **Bicycle**	How many **other** people are travelling w/ you? ______	☐ **On-Site**: Name of Business/Building __________ ☐ **Off-Site**: Address/Nearest Intersection __________ City (if other) __________	☐ **Walk**: Walked all the way ? ☐ Y ☐ N ☐ **Auto**: Did you park? ☐ Y -On-site ☐ Y - Off-site ☐ N Did you pay for parking? ☐ Y ☐ N Did you get dropped off? ☐ Y ☐ N ☐ **Bus**: Did you get off at a stop on-site? ☐ Y ☐ N ☐ **Train**: Did you get off at a stop on-site? ☐ Y ☐ N ☐ **Bicycle**	How many **other** people travelled w/ you)? ______	What time did you arrive here? ___:___ ☐ AM ☐ PM	Home Zip Code: ______ Age: ____ Sex: ☐ M ☐ F	~Age? ______ Sex: ☐ M ☐ F
___:___ ☐ AM ☐ PM	☐ **On-Site**: Name of Business/Building __________ ☐ **Off-Site**: Address/Nearest Intersection __________ & City (if other) ________	☐ **Walk**: Will you walk all the way ? ☐ Y ☐ N ☐ **Auto**: ☐ Drive parked car ☐ Passenger in parked car ☐ Get picked up ☐ **Bus**: Catch on-site? ☐ Y ☐ N ☐ **Train**: Catch on-site? ☐ Y ☐ N ☐ **Bicycle**	How many **other** people are travelling w/ you? ______	☐ **On-Site**: Name of Business/Building __________ ☐ **Off-Site**: Address/Nearest Intersection __________ City (if other) __________	☐ **Walk**: Walked all the way ? ☐ Y ☐ N ☐ **Auto**: Did you park? ☐ Y -On-site ☐ Y - Off-site ☐ N Did you pay for parking? ☐ Y ☐ N Did you get dropped off? ☐ Y ☐ N ☐ **Bus**: Did you get off at a stop on-site? ☐ Y ☐ N ☐ **Train**: Did you get off at a stop on-site? ☐ Y ☐ N ☐ **Bicycle**	How many **other** people travelled w/ you)? ______	What time did you arrive here? ___:___ ☐ AM ☐ PM	Home Zip Code: ______ Age: ____ Sex: ☐ M ☐ F	~Age? ______ Sex: ☐ M ☐ F
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___:___ ☐ AM ☐ PM	☐ **On-Site**: Name of Business/Building __________ ☐ **Off-Site**: Address/Nearest Intersection __________ & City (if other) ________	☐ **Walk**: Will you walk all the way ? ☐ Y ☐ N ☐ **Auto**: ☐ Drive parked car ☐ Passenger in parked car ☐ Get picked up ☐ **Bus**: Catch on-site? ☐ Y ☐ N ☐ **Train**: Catch on-site? ☐ Y ☐ N ☐ **Bicycle**	How many **other** people are travelling w/ you? ______	☐ **On-Site**: Name of Business/Building __________ ☐ **Off-Site**: Address/Nearest Intersection __________ City (if other) __________	☐ **Walk**: Walked all the way ? ☐ Y ☐ N ☐ **Auto**: Did you park? ☐ Y -On-site ☐ Y - Off-site ☐ N Did you pay for parking? ☐ Y ☐ N Did you get dropped off? ☐ Y ☐ N ☐ **Bus**: Did you get off at a stop on-site? ☐ Y ☐ N ☐ **Train**: Did you get off at a stop on-site? ☐ Y ☐ N ☐ **Bicycle**	How many **other** people travelled w/ you)? ______	What time did you arrive here? ___:___ ☐ AM ☐ PM	Home Zip Code: ______ Age: ____ Sex: ☐ M ☐ F	~Age? ______ Sex: ☐ M ☐ F
___:___ ☐ AM ☐ PM	☐ **On-Site**: Name of Business/Building __________ ☐ **Off-Site**: Address/Nearest Intersection __________ & City (if other) ________	☐ **Walk**: Will you walk all the way ? ☐ Y ☐ N ☐ **Auto**: ☐ Drive parked car ☐ Passenger in parked car ☐ Get picked up ☐ **Bus**: Catch on-site? ☐ Y ☐ N ☐ **Train**: Catch on-site? ☐ Y ☐ N ☐ **Bicycle**	How many **other** people are travelling w/ you? ______	☐ **On-Site**: Name of Business/Building __________ ☐ **Off-Site**: Address/Nearest Intersection __________ City (if other) __________	☐ **Walk**: Walked all the way ? ☐ Y ☐ N ☐ **Auto**: Did you park? ☐ Y -On-site ☐ Y - Off-site ☐ N Did you pay for parking? ☐ Y ☐ N Did you get dropped off? ☐ Y ☐ N ☐ **Bus**: Did you get off at a stop on-site? ☐ Y ☐ N ☐ **Train**: Did you get off at a stop on-site? ☐ Y ☐ N ☐ **Bicycle**	How many **other** people travelled w/ you)? ______	What time did you arrive here? ___:___ ☐ AM ☐ PM	Home Zip Code: ______ Age: ____ Sex: ☐ M ☐ F	~Age? ______ Sex: ☐ M ☐ F
___:___ ☐ AM ☐ PM	☐ **On-Site**: Name of Business/Building __________ ☐ **Off-Site**: Address/Nearest Intersection __________ & City (if other) ________	☐ **Walk**: Will you walk all the way ? ☐ Y ☐ N ☐ **Auto**: ☐ Drive parked car ☐ Passenger in parked car ☐ Get picked up ☐ **Bus**: Catch on-site? ☐ Y ☐ N ☐ **Train**: Catch on-site? ☐ Y ☐ N ☐ **Bicycle**	How many **other** people are travelling w/ you? ______	☐ **On-Site**: Name of Business/Building __________ ☐ **Off-Site**: Address/Nearest Intersection __________ City (if other) __________	☐ **Walk**: Walked all the way ? ☐ Y ☐ N ☐ **Auto**: Did you park? ☐ Y -On-site ☐ Y - Off-site ☐ N Did you pay for parking? ☐ Y ☐ N Did you get dropped off? ☐ Y ☐ N ☐ **Bus**: Did you get off at a stop on-site? ☐ Y ☐ N ☐ **Train**: Did you get off at a stop on-site? ☐ Y ☐ N ☐ **Bicycle**	How many **other** people travelled w/ you)? ______	What time did you arrive here? ___:___ ☐ AM ☐ PM	Home Zip Code: ______ Age: ____ Sex: ☐ M ☐ F	~Age? ______ Sex: ☐ M ☐ F

APPENDIX C. INSTRUCTIONS FOR DATA COLLECTORS

Data collector training is critical for obtaining reliable data at field study locations. The following points should be made whenever new data collectors arrive to a site. These points should be reiterated throughout the data collection process.

Key points should be made to door counters during training included:

- Understand the purpose of the study.
- Arrive at least 15 minutes before the start of the data collection period.
- Bring a watch or other device to keep track of five-minute periods.
- Bring a pencil and something to write on.
- Concentrate and count every single person accurately. Door counts are the most critical piece of information being used in the study.
- Count every person entering and exiting the doorway. However, do not count people who take out garbage, take a smoke break in front of the building, or other people who obviously enter and exit without going to another activity location.
- Do not talk to others. Also avoid other distractions during the data collection period, such as using mobile devices (e.g., phone calls, text messages, internet).
- Provide the one-page study information sheet to any person who asks them what they are doing; inform the data collection manager at the site if there are any problems with individuals.
- Show up on assigned data collection days. Even if the weather looks bad, assume that data will be collected until the data collection manager sends a cancellation notice. Data collection will be rescheduled on inclement weather days (i.e., ≥ 50% chance of rain predicted for the site at noon of the previous day on www.weather.com.)

Intercept surveyors should be trained to:

- Understand the purpose of the study and the specific information solicited by the surveys.
- Arrive at least 15 minutes before the start of the data collection period.
- Bring at least 50 survey forms per surveyor (space for 200 potential surveys or refusals).
- Be confident when approaching people to interview (assume that they will agree to participate), but be polite when people decline to participate. Do not bother people who do not want to participate.
- Obtain the necessary information from respondents. This may involve modifying the language of the survey questions so that they are understandable to each respondent at each location (i.e., do not read the survey questions as a script).
- Ask all questions on the full survey and just the essential questions on an abbreviated survey.
- Do not lead respondents by guessing answers for them.
- Obtain the all travel modes used on each trip, including walking to and from parking or transit stops.

- Record the time at the beginning of the survey.
- Record responses and information about non-respondents completely.
- Do not spend more time interviewing participants of the opposite gender.
- Avoid socializing with respondents who may want to discuss topics that are not on the survey.
- Keep the most direct pathway to and from the door clear when inviting people to participate and when administering surveys.
- Do not disrupt normal business activity at the study location.
- Provide the one-page study information sheet to any person who has questions about the study; inform the data collection manager at the site if there are any problems with individuals.
- Show up on assigned data collection days. Even if the weather looks bad, assume that data will be collected until the data collection manager sends a cancellation notice. Data collection will be rescheduled on inclement weather days (i.e., ≥ 50% chance of rain predicted for the site at noon of the previous day on www.weather.com.)

APPENDIX D. FIELD DATA QUALITY CHECKS

At the end of each data collection period, managers should review the door counts and data collection sheets for unclear responses, errors, or other discrepancies. It is important to do this check as soon as possible after data collection is complete while the data collector's memory is still fresh. This process will not catch every error, but it increases the accuracy of the counts and survey responses and helps the door count and survey personnel understand problems to avoid during any future collection period. The review of data collection sheets are completed most meticulously when data collectors first starting to learn the data collection process.

This check examined the following information on count sheets:

- Data collector's name and specific count location should be recorded on all sheets.
- The correct hour should be written at the top of each sheet.
- The count should cover the full data collection period.
- The balance of entry and exit counts should look reasonable for the time period observed.
- Variations by five-minute period should be logical.
- Total counts look should be reasonable.

The following aspects of the survey forms should be checked:

- Data collector's name and specific count location should be recorded on all sheets.
- Time, estimated age, and estimated gender should be recorded for survey refusals.
- Times of completed surveys should be recorded.
- Write-in responses should be complete and legible.
- All modes recorded for a specific trip should be logical.
- Destinations for egress trips recorded should be logical.
- Origins for access trips recorded should be logical.
- Times recorded for access trips should be logical (e.g., if the time of the access trip were after the egress trip, it would not make sense).
- Blank response items should be noted. Surveyors should be asked if they forgot to ask the question, if the participant didn't respond, or if they simply forgot to record the information on the sheet.

Door Count Form

(Use one sheet each hour. Write start time at top of each sheet.)

Site: ___________________________________ Name: ________________________________ Date: ___________

Time [Start ____:____ am/pm]	Direction	Location:____________		Location:____________		Location:____________	
		Male	Female	Male	Female	Male	Female
:00 to :04	In						
	Out						
:05 to :09	In						
	Out						
:10 to :14	In						
	Out						
:15 to :19	In						
	Out						
:20 to :24	In						
	Out						
:25 to :29	In						
	Out						
:30 to :34	In						
	Out						
:35 to :39	In						
	Out						
:40 to :44	In						
	Out						
:45 to :49	In						
	Out						
:50 to :54	In						
	Out						
:55 to :59	In						
	Out						

California Smart-Growth Trip Generation Rates Study

Final Report

Appendix F

Institute of Transportation Studies

University of California, Davis

Davis, CA 95616

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
December 2012

AUTHORS
Robert Schneider, Ph.D., University of California, Davis
Kevan Shafizadeh, Ph.D., California State University, Sacramento
Susan Handy, Ph.D., University of California, Davis

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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

Step 2: Estimate Ordinary Least Squares Regression Models

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

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[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:

$$\textit{Actual vehicle trips/ITE vehicle trips} = e^{(-0.155\times 1.723 - 0.529\times 1 - 0.744\times 0 - 0.079\times 0 - 0.311\times 0 - 0.491)} = 0.276$$

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:

$$\textit{Model-adjusted estimate of vehicle trips} = 0.276 \times 200 = 55$$

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

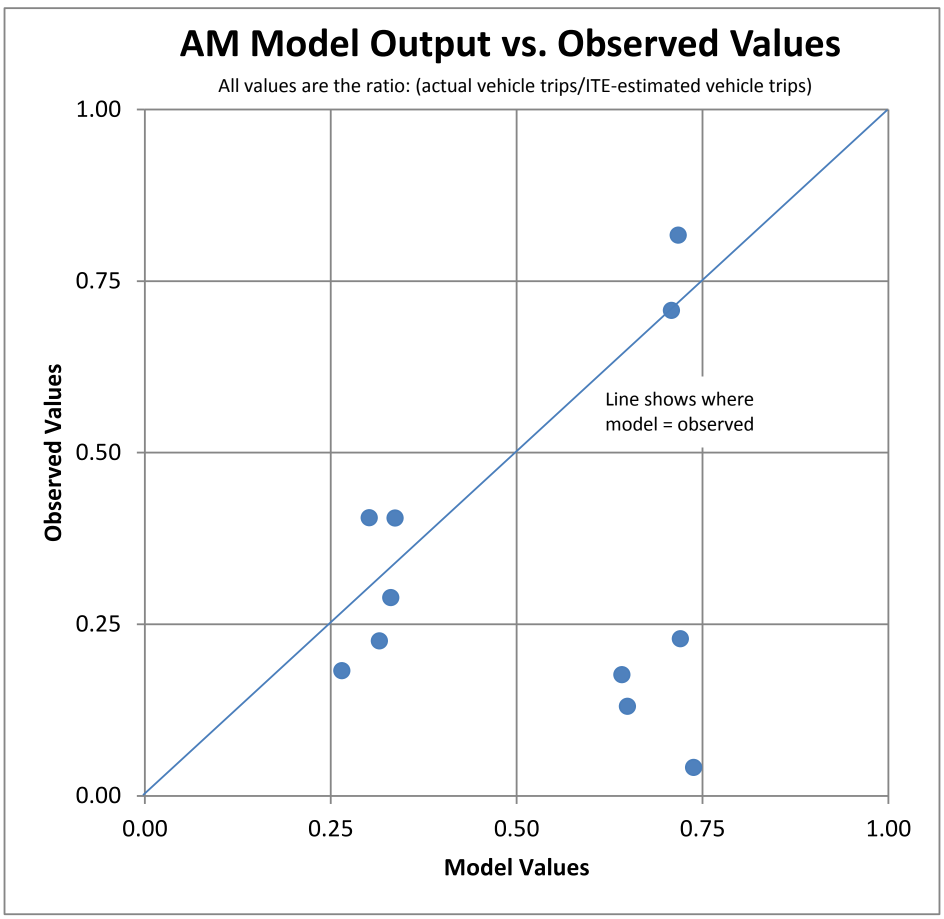

Figure 1. AM Model Validation Plot

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

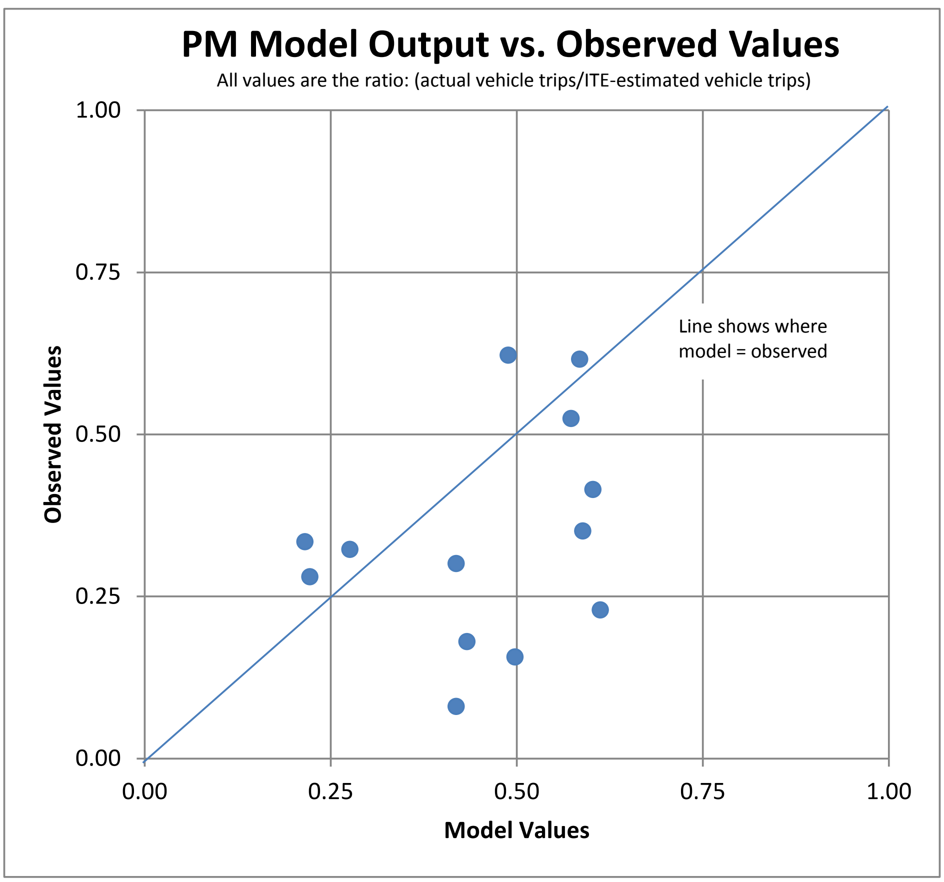

Figure 2. PM Model Validation Chart

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)					Data for Dependent Variables								Explanatory Variables								
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)	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	Los Angeles	Jamboree Center	1 Park Plaza	Irvine, CA	EPA MXD Study	X		X							X						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	Los Angeles	Park Place	3131 Michelson Drive	Irvine, CA	EPA MXD Study	X		X							X						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	Los Angeles	The Villages	38 Prism Drive	Irvine, CA	EPA MXD Study	X		X							X						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	San Diego	Rio Vista Station Village	2185 Station Village Way	San Diego, CA	SANDAG MXD Study	X		X							X						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	San Diego	La Mesa Village Plaza	4700 Spring Street	La Mesa, CA	SANDAG MXD Study	X		X							X						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	San Diego	Uptown Center	1270 Cleveland Avenue	San Diego, CA	SANDAG MXD Study	X		X							X						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	San Diego	The Village at Morena Linda Vista	5395 Napa Street	San Diego, CA	SANDAG MXD Study	X		X							X						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	San Diego	Hazard Center	7676 Hazard Center Drive	San Diego, CA	SANDAG MXD Study	X		X							X						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	San Diego	Heritage Center at Otay Ranch	1394 E. Palomar Street	Chula Vista, CA	SANDAG MXD Study	X		X							X						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	San Francisco	1388 Sutter Street	1388 Sutter Street	San Francisco, CA	Caltrans Infill Study	X		X			710							120,000	100%		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	San Diego	Atria	101 Market Street	San Diego, CA	Caltrans Infill Study	X		X					936							1,250	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	Los Angeles	10351 Santa Monica Boulevard	10351 Santa Monica Boulevard	Los Angeles, CA	Caltrans Infill Study	X		X			710							101,495	89%		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	Los Angeles	Wilshire Pacific Plaza	12301 Wilshire Boulevard	Los Angeles, CA	Caltrans Infill Study	X		X			710							105,977	80%		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	Los Angeles	Archstone Santa Monica on Main	2000 Main Street	Santa Monica, CA	Caltrans Infill Study	X		X		223						133	93%				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	Los Angeles	Archstone Pasadena	25 South Oak Knoll Avenue	Pasadena, CA	Caltrans Infill Study	X		X		223						120	95%				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	San Francisco	Pazzia Caffe and Trattoria	337 3rd Street	San Francisco, CA	Caltrans Infill Study	X		X						931						3,000	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	East Bay	Mission Wells	39128 Guardino Drive	Fremont, CA	TCRP Report 128	X		X		220						391	*100%*				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	East Bay	Montelena Apartment Homes	655 Tennyson Road	Hayward, CA	TCRP Report 128	X		X		220						188	*100%*				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	East Bay	Park Regency	3128 Oak Road	Walnut Creek, CA	TCRP Report 128	X		X		220						854	*100%*				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	East Bay	Verandas	33 Union Square	Union City, CA	TCRP Report 128	X		X		220						282	*100%*				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	East Bay	Wayside Commons	3183 Wayside Plaza	Walnut Creek, CA	TCRP Report 128	X		X		230						156	*100%*				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	San Francisco	Larkspur Landing	2001 Larkspur Landing Circle	Larkspur, CA	Fehr & Peers	X		X							X						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	East Bay	Bay Street	5616 Bay Street	Emeryville, CA	Fehr & Peers	X		X							X						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	East Bay	Fine Arts Building	2110 Haste Street	Berkeley, CA	Caltrans Infill Study	X		X		223						100	100%				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	East Bay	Berkeleyan Apartments	1910 Oxford Street	Berkeley, CA	Caltrans Infill Study	X		X					936							4,500	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	East Bay	Acton Courtyard	1370 University Avenue	Berkeley, CA	Caltrans Infill Study	X		X		223						71	100%				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	San Francisco	343 Sansome	343 Sansome Stret	San Francisco, CA	UCD Data Collection	X		X			710							256,985	89%		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	East Bay	Oakland City Center	1333 Broadway	Oakland, CA	UCD Data Collection	X		X			710							239,821	80%		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	Los Angeles	Sakura Crossing	235 S. San Pedro Street	Los Angeles, CA	UCD Data Collection	X		X		223						230	96%				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	Los Angeles	Artisan on 2nd	601 E. Second Street	Los Angeles, CA	UCD Data Collection	X		X		223						118	96%				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	Los Angeles	Victor on Venice	10001 Venice Boulevard	Los Angeles, CA	UCD Data Collection	X		X		223						116	95%				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	East Bay	The Sierra	311 Oak Street	Oakland, CA	UCD Data Collection	X		X		223						224	98%				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	East Bay	180 Grand Avenue	180 Grand Avenue	Oakland, CA	UCD Data Collection	X		X			710							277,789	63%		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	Los Angeles	Archstone at Del Mar Station	265 Arroyo Parkway	Pasadena, CA	UCD Data Collection	X		X		223						235	94%				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	East Bay	Terraces at Emery Station	5855 Horton Street	Emeryville, CA	UCD Data Collection	X		X		223						101	100%				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	Los Angeles	Holly Street Village	151 E. Holly Street	Pasadena, CA	UCD Data Collection	X		X		223						374	95%				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	East Bay	Emery Station East	5885 Hollis Street	Emeryville, CA	UCD Data Collection	X		X			710							247,619	*95%*		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	East Bay	Broadway Grand	438 W. Grand Avenue	Oakland, CA	UCD Data Collection	X		X					936							*1,300*	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	Los Angeles	Terraces Apartment Homes	375 E. Green Street	Pasadena, CA	UCD Data Collection	X		X		223						276	94%				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	San Francisco	181 Second Avenue	181 2nd Avenue	San Mateo, CA	UCD Data Collection	X		X			710							50,600	99%		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	San Francisco	Argenta	1 Polk Street	San Francisco, CA	UCD Data Collection	X		X		222						187	95%				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	San Francisco	Charles Schwab Building	211 Main Street	San Francisco, CA	UCD Data Collection	X		X			710							417,245	77%		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	Sacramento	Park Tower	980 9th Street	Sacramento, CA	UCD Data Collection	X		X			710							462,476	90%		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	Sacramento	Fremont Building	1501 16th Street	Sacramento, CA	UCD Data Collection	X		X		223						69	96%				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	San Francisco	Convention Plaza	201 3rd Street	San Francisco, CA	UCD Data Collection	X		X			710							323,000	96%		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	Los Angeles	Pegasus	612 S. Flower Street	Los Angeles, CA	UCD Data Collection	X				222						322	96%				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	East Bay	Chain Clothing Store	1333 Broadway	Oakland, CA	Caltrans Infill Study			X				820								11,000	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	East Bay	Gaia Building	2116 Allston Way	Berkeley, CA	Caltrans Infill Study			X		223						99	99%				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	East Bay	Bachenheimer Building	2111 University Avenue	Berkeley, CA	Caltrans Infill Study			X				820								3,000	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	East Bay	Fruitvale Station	3100 E. 9th Street	Oakland, CA	UCD Data Collection			X				867								30,037	40	66		102			0.65	-0.43	0.50	3.79	6.62	3.14	208	0	23.00	3.00	0
223.1	Sacramento	Park Plaza	1303 J Street	Sacramento, CA	UCD Data Collection			X			710							72,649	88%		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	Los Angeles	Central City Association of Los Angeles	626 Wilshire Boulevard	Los Angeles, CA	Caltrans Infill Study		X		X		710							138,542	98%		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	San Diego	Horizon	555 Front Street	San Diego, CA	Caltrans Infill Study		X		X	232						211	100%				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	San Diego	Atria	101 Market Street	San Diego, CA	Caltrans Infill Study		X		X	230						149	100%				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	San Francisco	Archstone Fox Plaza	1390 Market Street	San Francisco, CA	Caltrans Infill Study		X		X	222						443	95%				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	San Francisco	Bong Su	311 3rd Street	San Francisco, CA	Caltrans Infill Study		X		X					931						6,000	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	East Bay	Berkeleyan Apartments	1910 Oxford Street	Berkeley, CA	Caltrans Infill Study		X		X	223						56	100%				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	East Bay	Acton Courtyard	1370 University Avenue	Berkeley, CA	Caltrans Infill Study		X		X					939						5,000	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	East Bay	Broadway Grand	438 W. Grand Avenue	Oakland, CA	UCD Data Collection		X		X	223						130	82%				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	Sacramento	Park Tower	980 9th Street	Sacramento, CA	UCD Data Collection		X		X				936							1,652	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	San Francisco	Convention Plaza	201 3rd Street	San Francisco, CA	UCD Data Collection		X		X				936							1,556	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	San Francisco	343 Sansome	343 Sansome Stret	San Francisco, CA	UCD Data Collection		X						936							1,097	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	East Bay	Touriel Building	2004 University Avenue	Berkeley, CA	Caltrans Infill Study				X	223						35	97%				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	East Bay	Bachenheimer Building	2111 University Avenue	Berkeley, CA	Caltrans Infill Study				X	223						44	100%				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	Los Angeles	Paseo Colorado	280 E. Colorado Boulevard	Pasadena, CA	UCD Data Collection				X			820								497,564		770	498	1856			0.41	-0.88	0.00	22.59	8.45	9.23	0	1	18.00	2.00	0
					Totals by Category:	46	11	50	13	28	13	4	6	3	11																						

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

Exit Intercept Survey: As persons EXIT, intercept as they leave a specific entrance.

Interviewer Name:_____________________________ **Building:** ___________________________ **Location:** __________________________**Date:** _____________ **Start Time:** ______:______ **am pm** **Page** _______ **of** _______

"Hello! Do you a have a minute to take a brief smart-growth transportation survey?" (This survey is for a research project led by UC Davis for Caltrans. Feel free to decline to answer any questions you are not comfortable with.)

Time of Trip	THE TRIP YOU ARE TAKING NOW…	THE TRIP YOU TOOK TO GET HERE…		THE TRIP YOU ARE TAKING NOW…	THE TRIP YOU TOOK TO GET HERE…	Other Info (Ask all.)	Refusal?
	How are you getting there? (Check **all** that apply.)	**Was it betw 7-10 am or 4-7 pm?**	**If yes, how did you get here?** (Check **all** that apply.)	**Where are you going?** (Check **one** only.)	**Where did you come?** (Check **one** only.)		
__:__ ☐ AM ☐ PM	☐ **Walk**: Will you walk all the way ? ☐ Y ☐ N ☐ **Auto**: ☐ Driver ☐ Passenger How many **other** people are travelling with you? ______ ☐ **Bus**: Catch on-site? ☐ Y ☐ N ☐ **Train**: Catch on-site? ☐ Y ☐ N ☐ **Bicycle** ☐ **Other**__________	☐ Yes ☐ No If Yes, when? ____:_____ ☐ AM ☐ PM	☐ **Walk**: Walked all the way ? ☐ Y ☐ N ☐ **Auto**: Did you park? ☐ Y -On-site ☐ Y - Off-site ☐ N Did you pay for parking? ☐ Y ☐ N Were you the driver? ☐ Y ☐ N How many **other** people travelled with you? ___ ☐ **Bus**: Did you get off at a stop on-site? ☐ Y ☐ N ☐ **Train**: Did you get off at a stop on-site? ☐ Y ☐ N ☐ **Bicycle** ☐ **Other** ________________	☐ **On-Site**: Name of Business/Building ______________________________ ☐ **Off-Site**: Address/Nearest Intersection ______________________________ & City (if other) ________________	☐ **On-Site**: Name of Business/Building ______________________________ ☐ **Off-Site**: Address/Nearest Intersection ______________________________ City (if other) ________________	Home Zip Code: ________ Age: ____ Sex: ☐ M ☐ F	~Age? ______ Sex: ☐ M ☐ F
Did you take any other trips today to or from this building between 7-10 am or 4-7 pm? ☐ Y ☐ N If yes, use more row(s) as needed:							
__:__ ☐ AM ☐ PM	☐ **Walk**: Will you walk all the way ? ☐ Y ☐ N ☐ **Auto**: ☐ Driver ☐ Passenger How many **other** people are travelling with you? ______ ☐ **Bus**: Catch on-site? ☐ Y ☐ N ☐ **Train**: Catch on-site? ☐ Y ☐ N ☐ **Bicycle** ☐ **Other**__________	☐ Yes ☐ No If Yes, when? ____:_____ ☐ AM ☐ PM	☐ **Walk**: Walked all the way ? ☐ Y ☐ N ☐ **Auto**: Did you park? ☐ Y -On-site ☐ Y - Off-site ☐ N Did you pay for parking? ☐ Y ☐ N Were you the driver? ☐ Y ☐ N How many **other** people travelled with you? ___ ☐ **Bus**: Did you get off at a stop on-site? ☐ Y ☐ N ☐ **Train**: Did you get off at a stop on-site? ☐ Y ☐ N ☐ **Bicycle** ☐ **Other** ________________	☐ **On-Site**: Name of Business/Building ______________________________ ☐ **Off-Site**: Address/Nearest Intersection ______________________________ & City (if other) ________________	☐ **On-Site**: Name of Business/Building ______________________________ ☐ **Off-Site**: Address/Nearest Intersection ______________________________ City (if other) ________________	Home Zip Code: ________ Age: ____ Sex: ☐ M ☐ F	~Age? ______ Sex: ☐ M ☐ F
Did you take any other trips today to or from this building between 7-10 am or 4-7 pm? ☐ Y ☐ N If yes, use more row(s) as needed:							
__:__ ☐ AM ☐ PM	☐ **Walk**: Will you walk all the way ? ☐ Y ☐ N ☐ **Auto**: ☐ Driver ☐ Passenger How many **other** people are travelling with you? ______ ☐ **Bus**: Catch on-site? ☐ Y ☐ N ☐ **Train**: Catch on-site? ☐ Y ☐ N ☐ **Bicycle** ☐ **Other**__________	☐ Yes ☐ No If Yes, when? ____:_____ ☐ AM ☐ PM	☐ **Walk**: Walked all the way ? ☐ Y ☐ N ☐ **Auto**: Did you park? ☐ Y -On-site ☐ Y - Off-site ☐ N Did you pay for parking? ☐ Y ☐ N Were you the driver? ☐ Y ☐ N How many **other** people travelled with you? ___ ☐ **Bus**: Did you get off at a stop on-site? ☐ Y ☐ N ☐ **Train**: Did you get off at a stop on-site? ☐ Y ☐ N ☐ **Bicycle** ☐ **Other** ________________	☐ **On-Site**: Name of Business/Building ______________________________ ☐ **Off-Site**: Address/Nearest Intersection ______________________________ & City (if other) ________________	☐ **On-Site**: Name of Business/Building ______________________________ ☐ **Off-Site**: Address/Nearest Intersection ______________________________ City (if other) ________________	Home Zip Code: ________ Age: ____ Sex: ☐ M ☐ F	~Age? ______ Sex: ☐ M ☐ F
Did you take any other trips today to or from this building between 7-10 am or 4-7 pm? ☐ Y ☐ N If yes, use more row(s) as needed:							
__:__ ☐ AM ☐ PM	☐ **Walk**: Will you walk all the way ? ☐ Y ☐ N ☐ **Auto**: ☐ Driver ☐ Passenger How many **other** people are travelling with you? ______ ☐ **Bus**: Catch on-site? ☐ Y ☐ N ☐ **Train**: Catch on-site? ☐ Y ☐ N ☐ **Bicycle** ☐ **Other**__________	☐ Yes ☐ No If Yes, when? ____:_____ ☐ AM ☐ PM	☐ **Walk**: Walked all the way ? ☐ Y ☐ N ☐ **Auto**: Did you park? ☐ Y -On-site ☐ Y - Off-site ☐ N Did you pay for parking? ☐ Y ☐ N Were you the driver? ☐ Y ☐ N How many **other** people travelled with you? ___ ☐ **Bus**: Did you get off at a stop on-site? ☐ Y ☐ N ☐ **Train**: Did you get off at a stop on-site? ☐ Y ☐ N ☐ **Bicycle** ☐ **Other** ________________	☐ **On-Site**: Name of Business/Building ______________________________ ☐ **Off-Site**: Address/Nearest Intersection ______________________________ & City (if other) ________________	☐ **On-Site**: Name of Business/Building ______________________________ ☐ **Off-Site**: Address/Nearest Intersection ______________________________ City (if other) ________________	Home Zip Code: ________ Age: ____ Sex: ☐ M ☐ F	~Age? ______ Sex: ☐ M ☐ F

Draft Final Report

Verification and Re-estimation of the Smart Growth Trip Generation Model with Portland Data

University of California, Davis for the California Department of Transportation
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Authors

Andrew McFadden

Robert Schneider

Kevan Shafizadeh

Susan Handy

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DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the accuracy of information presented herein. The contents do not necessarily reflect the official views or policies of the State of California or the Federal Highway Administration (FHWA). This report and other project products do not constitute a standard, specification, or regulation.

Contents

1. Introduction

The Institute of Transportation Engineers' *Trip Generation Manual* provides estimates of the number of trips per unit size that a new development is likely to generate. Most of the data on which ITE bases its trip-generation rates is obtained at suburban locations. As a result, these rates may not accurately reflect the trip generation patterns at smart growth sites where close proximity to other destinations as well as transit and bike facilities make non-vehicular forms of travel more prevalent.

To address this bias, Schneider et al. (2013a) developed a methodology for producing more accurate trip-generation rates for smart growth sites across California. The project produced a data collection methodology, a smart growth factor incorporating 8 variables representing the degree to which a site reflects smart growth characteristics, trip generation adjustment models for both AM and PM peak hours, and a spreadsheet tool for use by practitioners. The trip-generation models were based on data from more than 50 sites in California. Validation of these models was conducted using data from several sites left out of the estimation process. Table 1 lists the appendices included in the original study that provide further information on specific components of the project.

Table 1. Appendices to Original Report

Appendix A. Definition of "smart growth"
Appendix B. Annotated review of land use & transportation literature
Appendix C. Summary & comparison of existing tools worldwide
Appendix D. Evaluation of the operation & accuracy of available methodologies
Appendix E. UCD's Data Collection Methodology and Results
Appendix F. Method for Adjusting ITE Trip Generation Estimates for Smart Growth Projects Smart Growth Trip-Generation Adjustment Tool

This report outlines follow-up work done to test and improve the PM model developed in the original study. The follow-up work supplements the original trip generation data collected in California with data collected at 78 sites in the Portland region by Kelly Clifton and others (2012) at Portland State University. These new sites were located across the Portland area in both smart growth and non-smart growth developments. The following sections describe the work done to verify the original model, re-estimate a new PM model based on the combined dataset, and conduct validation on the re-estimated model.

2. Verification of Original Model

The section describes the results of our application of the original PM peak-hour smart growth trip generation model (Schneider et al., 2013b) to the78 sites in the Portland metro area. The model was used to estimate vehicle trips for these sites taking into account their smart growth characteristics (or lack thereof) and the resulting estimates were compared to observed vehicle trips. This verification process was performed to test both the predictive power and applicability of the original model for an independent data set.

The 78 sites from Portland consisted of three different land uses: sit down restaurants, convenience stores, and drinking places. The numbers of sites in the dataset for each of these land uses are shown in Table 2. For each of these sites, we assembled data on the smart growth characteristics used in the original SGTG model.

Table 2. Land Uses of Portland Data

ITE Land Use Code	Land Use Name	Frequency	Percent of Sample
932	High-Turnover (Sit-Down) Restaurant	39	50%
851	Convenience Market	26	33%
925	Drinking Place	13	17%
Total		78	100%

The original study (Schneider et al., 2013a) outlined several key criteria that a site must meet for the model to be applicable. These criteria, established through consultation with a Practitioners Panel, are shown in Table 3. Each of the 78 Portland sites was checked for consistency with the criteria for applying the model.

Table 3. Criteria for Applying Original Smart Growth Trip Generation Model (Schneider et al., 2013a)

Land Uses	ITE Trip Generation Land Use Codes: Residential (220, 222, 223, 230, 232), office (710), restaurant (925, 931), and coffee/donut shop (936); potentially applicable to retail land use codes.
Development Intensity	▪ The area within a 0.5-mile radius of the site is mostly developed, and ▪ There is a mix of land uses within a 0.25-mile radius of the site, and ▪ 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, and ▪ There are no special attractors within a 0.25-mile radius of the site (e.g., stadiums, military bases, commercial airports, etc).
Transit Service	During a typical weekday PM peak hour, there are at least 10 bus stop locations on all bus lines that pass within any part of a 0.25-mile radius around the study site, or 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.
Pedestrian or Bicycle Infrastructure	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), or there is >50% sidewalk coverage on streets within a 0.25-mile radius of the site.

Based on these criteria, the Portland sites were grouped into the following three categories:

- *Most Appropriate:* 4 sites met all criteria, and 16 met all but the land use requirement (20 sites total).
- *Nearly Appropriate:* 23 met nearly all criteria.
- *Least Appropriate:* 35 did not meet the criteria to be evaluated in the model.

Out of the 78 sites, only four met all criteria. Yet, as many of the restaurant and convenience store land-use types closely matched uses at the site on which the original model was based, 16 additional sites that met all but the land use requirement were added to these four to define the Primary Analysis Set (N = 20). Twenty-three sites were identified that nearly met all the criteria of the original model, where "nearly" was defined as meeting all criteria at half their original threshold (i.e., 5 train stops instead of 10). Although 50% is an arbitrary threshold, we concluded that these sites displayed adequate smart growth qualities to be tested with the model. These 23 sites were added to the Primary Analysis Set to create the Secondary Analysis Set (N = 43). The last 35 sites did not meet the original criteria or the relaxed criteria for the Secondary Analysis Set, but they were still analyzed as a part of the Full Analysis Set (N = 78).

The original model used site attributes to predict the adjustment to ITE-based trip estimates (equation 1).

$$\boldsymbol{ln}\frac{\boldsymbol{Actual\ Peak\ Vehicle\ Trips}}{\boldsymbol{ITE\ Estimated\ Peak\ Vehicle\ Trips}} \quad (1)$$

For the verification analysis, we used the exponent of this expression (e^x), that is, the ratio of actual trips to the ITE estimate (equation 2).

$$Actual\ Peak\ Vehicle\ Trips \big/ ITE\ Estimated\ Peak\ Vehicle\ Trips \quad (2)$$

This ratio is used in the verification analysis in two different ways:

1) to compare the observed vehicle trips at a site to the ITE-based estimate, and
2) to compare the model-predicted vehicle trips at a site to the ITE-based estimate.

The figures below compare (1) on the y-axis and (2) on the x-axis. A perfect model would trend along the diagonal line shown in each figure (i.e. model-predicted trips would equal observed trips). Figure 1 shows this comparison for only the most appropriate Primary Analysis Set, while Figure 2 and Figure 3 present this comparison for the Secondary Analysis Set and Full Analysis Set, respectively (with the 23 nearly appropriate sites shown in red, and the 35 least appropriate sites shown in purple). Figures 1 through 3 show the complete results of each subsample, including all outliers. To obtain the predicted number of peak-vehicle trips, we multiplied the ratio shown in equation 2, above, by the ITE estimate. Figure 4 shows the ITE-estimated and model-predicted vehicle trips plotted against actual trips for the Primary Analysis Set (most appropriate sites only) in order of increasing vehicle trips.

Some sites had vehicle trip counts far higher than the ITE-based estimates. For example, the Hot Lips Pizza site at 721 NW 9th Avenue was identified as an outlier in the Primary Analysis Set with actual trips more than twice the number of trips estimated by ITE despite having smart-growth characteristics (Figure 1). As discussed below, restaurants displayed higher variability in actual trips than other land uses, and further work is needed to understand these variations.

The goodness of fit of the model is shown by how closely the estimates correspond with the perfect linear fit line provided in Figures 1, 2, and 3. As expected, the model was less accurate at predicting trip generation at sites that did not meet the smart-growth criteria set for the model. In general, the model provided a more accurate prediction of the observed PM peak-hour vehicle trips at smart growth sites with 75% of the most appropriate sites predicted closer to the actual estimate than the ITE prediction (Figure 4).

The results of this follow-up study verify the previously estimated model on a new dataset and validate the initial criteria placed on potential sites for use with the model. Yet, as only a few of the Portland sites met the criteria for applying the model, further work is needed to make the model more robust across a wider range of site characteristics. As a first step, we re-estimated the model with the combined data from the Portland and original California sites.

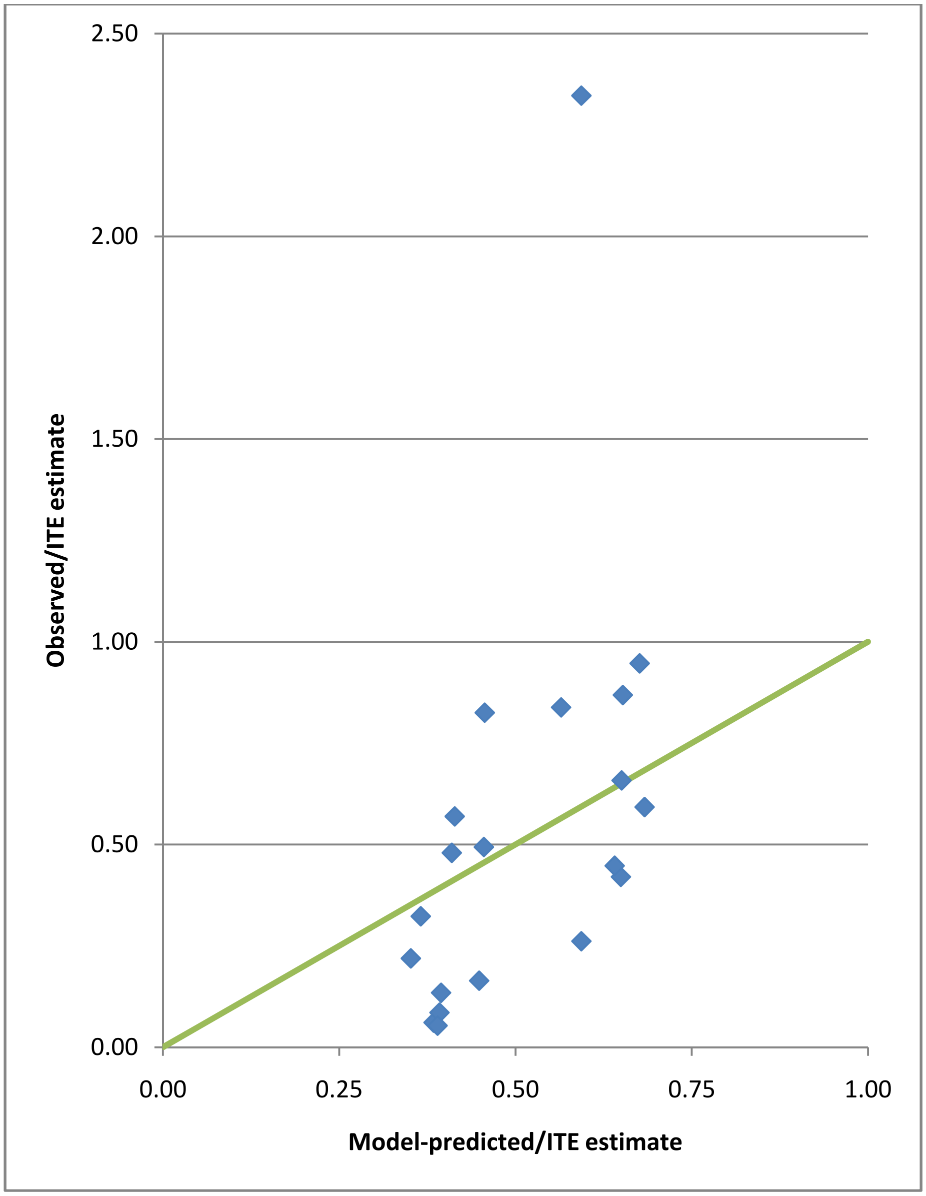

Figure 1. Observed versus Predicted Ratios to ITE Estimates: Most Appropriate Sites

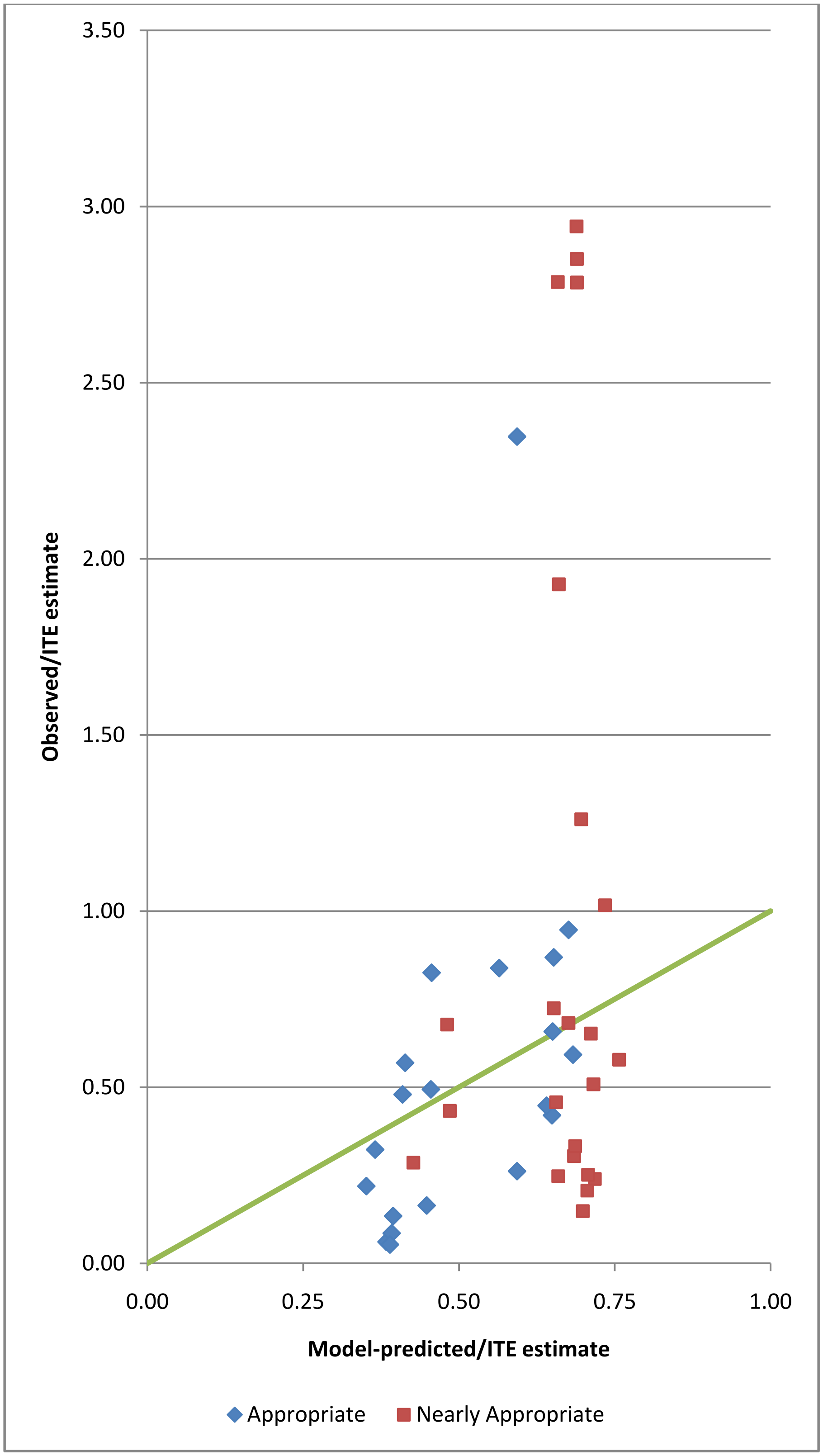

Figure 2. Observed versus Predicted Ratios to ITE Estimates: Most Appropriate and Nearly Appropriate Sites

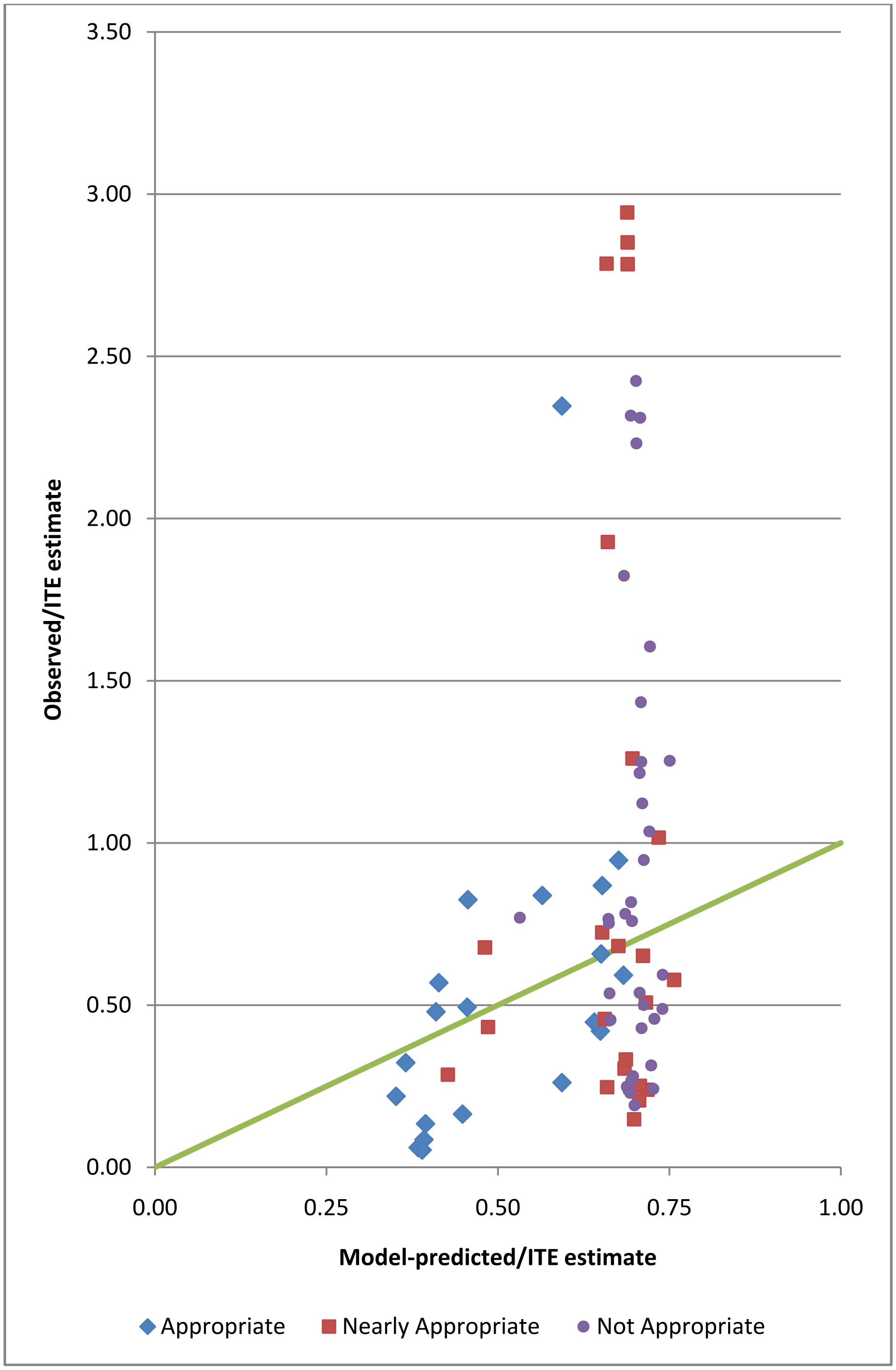

Figure 3. Observed versus Predicted Ratios to ITE Estimates: All Sites

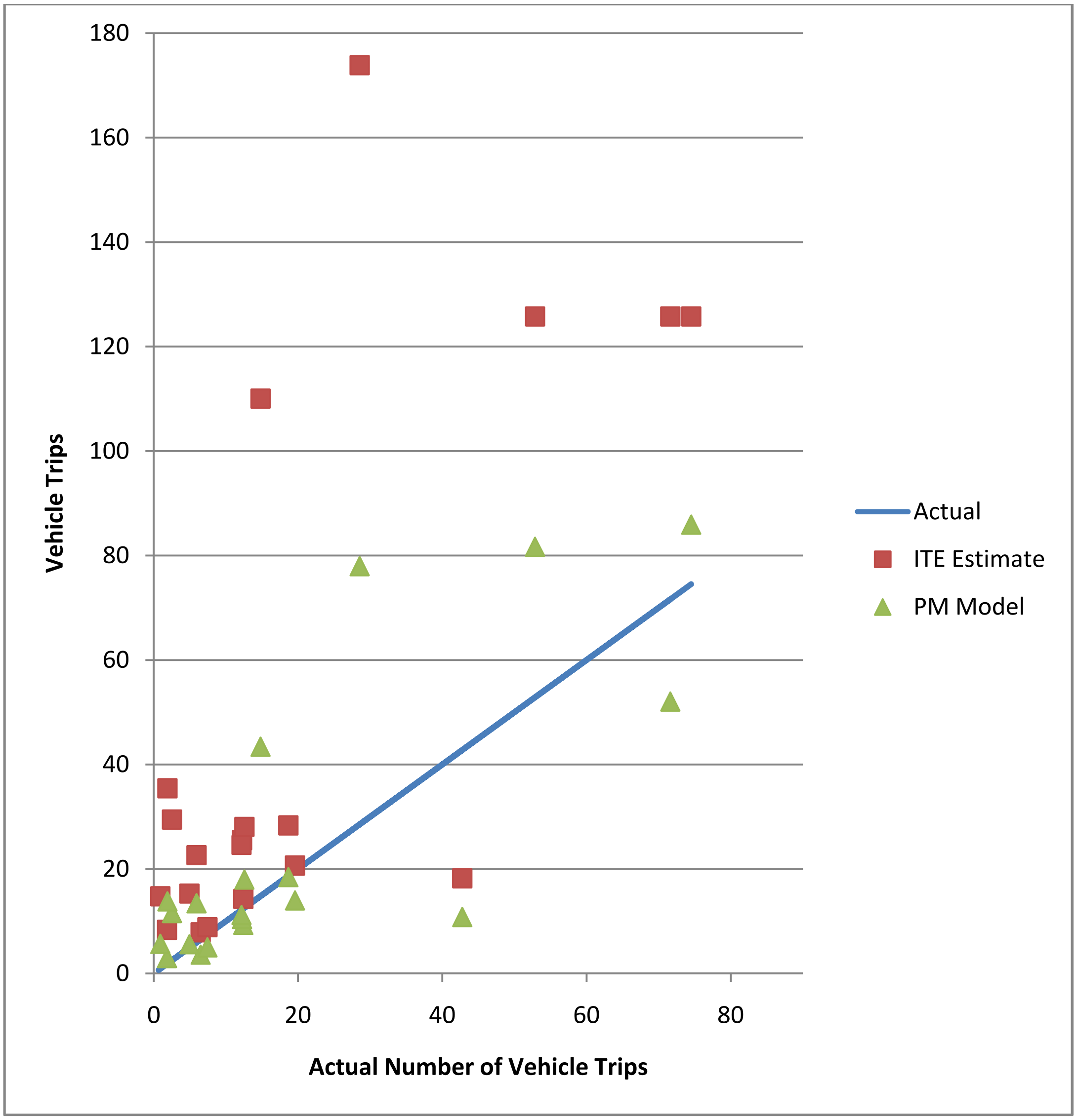

Figure 4. ITE- and Model- Estimated Trips vs. Actual Trips: Most Appropriate Sites

3. Re-estimating Original Model with New Portland Data

The following section describes the process of re-estimating the California SGTG model using the Portland data. The process involved 1) selecting sites for analysis and validation, 2) re-estimating the Smart-Growth Factor, and 3) re-estimating the linear regression model predicting the value shown in equation 1 above.

Although relatively few of the potential Portland sites met the criteria for application of the smart growth model, as described above, all Portland sites (N=78) were used to either re-estimate the model (N=64) or validate the new model (N=14). This new combined data set thus represents more diverse land use contexts than the sites used to estimate the California SGTG model. Figure below shows the validation and estimation sites with an inset map to magnify sites clustered in Downtown Portland. The validation sites were selected using a similar process as in the original analysis: when two sites were within a quarter of a mile of each other, one was randomly selected for the validation subset. This helps to ensure that sites in the estimation set are not correlated with each other based upon location. The 14 Portland sites selected in this way (shown in blue below in Figure 5) were combined with the 13 original California validation sites for the validation of the new model, described below. The SGTG model was re-estimated using 114 sties, 64 from Portland and 50 from California.

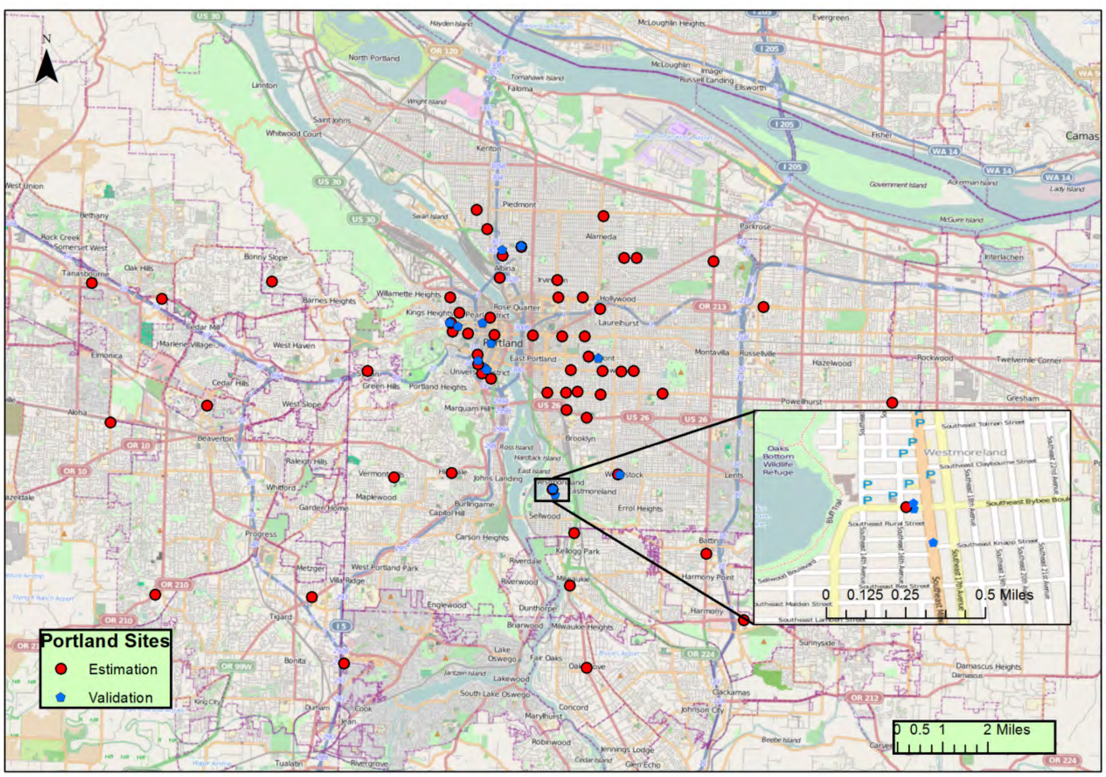

Figure 5. Validation and Estimation Sites from Portland Data

The next step was to re-estimate the Smart-Growth Factor using the expanded data set. Table 4 compares the factor loadings for the original and new factor analyses for the Smart-Growth Factor. Although the loadings on both straight-line distance to CBD and building setback decrease substantially (highlighted), they both conceptually relevant to retain in the Smart-Growth Factor. Their retention is supported by guidance from Costello and Osbourne (2005), who suggest that variables with factor loadings greater than an absolute value of 0.32 may be relevant to include. We also analyzed specifications with more than one factor but found the single-factor solution preferable, as in the original study. Table 5 shows the original and updated factor scores for the 8 variables making up the Smart-Growth Factor.

Table 4. Original and New Factor Loadings for Smart-Growth Factor

Variable	Original Loading	New Loading	Change in Magnitude
Residential population within an 804m (0.5-mile), straight-line radius (000s)	0.538	0.617	0.079
Jobs within an 804m (0.5-mile), straight-line radius (000s)	0.781	0.830	0.049
Straight-line distance to center of central business district (CBD) (miles)	-0.632	-0.397	-0.235
Average building setback distance from sidewalk (feet)	-0.636	-0.372	-0.264
Metered on-street parking within a 161m (0.1-mile), straight-line radius (1=yes, 0=no)	0.707	0.791	0.084
Individual PM peak-hour bus line stops passing within a 402m (0.25-mile), straight-line radius	0.745	0.789	0.044
Individual PM peak-hour train line stops passing within a 804m (0.5-mile), straight-line radius	0.661	0.678	0.017
Proportion of site area covered by surface parking lots (0.00 to 1.00)	-0.467	-0.508	0.041

Table 5. Original and New Factor Scores for Smart-Growth Factor

Variable	Original Scores	New Scores
Residential population within an 804m (0.5-mile), straight-line radius (000s)	0.099	0.129
Jobs within an 804m (0.5-mile), straight-line radius (000s)	0.324	0.317
Straight-line distance to center of central business district (CBD) (miles)	-0.138	-0.064
Average building setback distance from sidewalk (feet)	-0.167	-0.075
Metered on-street parking within a 161m (0.1-mile), straight-line radius (1=yes, 0=no)	0.184	0.282
Individual PM peak-hour bus line stops passing within a 402m (0.25-mile), straight-line radius	0.227	0.221
Individual PM peak-hour train line stops passing within a 804m (0.5-mile), straight-line radius	0.053	0.111
Proportion of site area covered by surface parking lots (0.00 to 1.00)	-0.080	-0.049

To calculate the Smart-Growth Factor for each of the 114 sites, the new factors scores for each variable were multiplied by the standardized values for each of the variables and the products were summed.[1] Table 6 shows the updated descriptive statistics with the Portland sites included.

Table 6. Smart-Growth Factor Variable Descriptive Statistics base on 114 PM Peak Hour Study Sites

Variable	N	Minimum	Maximum	Mean	Std. Dev.
Residential population within an 804m (0.5-mile), straight-line radius (000s)	114	0.41	42.11	7.84	5.43
Jobs within an 804m (0.5-mile), straight-line radius (000s)	114	0.17	136.40	14.49	22.99
Straight-line distance to center of central business district (CBD) (miles)	114	0.03	40.10	5.78	7.14
Average building setback distance from sidewalk (feet)	114	0.00	524.00	56.68	85.86
Metered on-street parking within a 161m (0.1-mile), straight-line radius (1=yes, 0=no)	114	0.00	1.00	0.35	0.48
Individual PM peak-hour bus line stops passing within a 402m (0.25-mile), straight-line radius	114	0.00	255.00	27.39	39.43
Individual PM peak-hour train line stops passing within a 804m (0.5-mile), straight-line radius	114	0.00	64.00	6.67	13.71
Proportion of site area covered by surface parking lots (0.00 to 1.00)	114	0.00	0.75	0.25	0.25

The third step was to use the calculated Smart-Growth Factor for each estimation site as an explanatory variable in re-estimating the SGTG model that predicts the adjustment to ITE-based estimates of vehicle trips (equation 1) for the PM peak hour. The first model tested (shown below in Table 7) included the same variables as in the original model: the Smart-Growth Factor, three land-use indicator variables, and a dummy variable for proximity to a university. All coefficient signs in the new model match those of the original model, but the new model has a much lower adjusted R^2 than the original model. The Smart-Growth Factor and University indicator variables both became larger in absolute magnitude and more significant statistically, while the opposite was true for the land-use indicator variables.

Table 7. Original Model Re-Estimated with Expanded Dataset

Dependent Variable = Natural Logarithm of Ratio of Actual Peak Hour Vehicle Trips to ITE-Estimated Peak Hour Vehicle Trips						
	Original PM Model			New PM Model		
Model Variables	Coefficient	t-statistic	p-value	Coefficient	t-statistic	p-value
Smart-Growth Factor (SGF)	-0.155	-1.491	0.143	-0.174	-1.929	0.056
Office land use (1 = yes, 0 = no)	-0.529	-2.558	0.014	-0.452	-1.754	0.082
Coffee shop land use (1 = yes, 0 = no)	-0.744	-2.339	0.024	-0.693	-1.733	0.086
Multi-use development (1 = yes, 0 = no)	-0.079	-0.381	0.705	-0.078	-0.359	0.721
Within 1 mi. of a university (1 = yes, 0 = no)	-0.311	-1.099	0.278	-0.359	-1.629	0.106
Constant	-0.491	-4.469	0.000	-0.460	-5.651	0.000
Overall Model						
Sample Size (N)	50			114		
Adjusted R^2-Value	0.290			0.158		
F-Value (Test value)	4.99 (p = 0.001)			5.23 (p =0.0002)		

[1] $SGFn = \sum_i Score_i \times \left(\frac{x_{in}-\mu_i}{s_i}\right)$ where *x* is variable *i*'s value for site *n*, μ is the sample mean, and *s* is variable *i*'s sample standard deviation.

To test the statistical significance of the changes in the coefficients, we calculated t-statistics using Equation 3, with degrees of freedom calculated using Equation 4. The results of this test are presented in Table 8.

$$\frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \quad (3)$$

$$\frac{\left({s_1}^2/n_1 + {s_2}^2/n_2\right)^2}{\left[\left({s_1}^2/n_1\right)^2/(n_1-1)\right] + \left[\left({s_2}^2/n_2\right)^2/(n_2-1)\right]} \quad (4)$$

Table 8. T-tests Performed on Original and New Model Coefficient Differences

	Original PM Model		New PM Model		Test of Difference			
Model Variables	**Coefficient**	**Std. error**	**Coefficient**	**Std. error**	**Coefficient Difference**	**t-statistic**	**d.f.**	**p value**
Smart-Growth Factor (SGF)	-0.155	0.104	-0.174	0.090	-0.019	-1.146	82.944	0.255
Office land use	-0.529	0.207	-0.452	0.257	0.077	2.043	115.195	0.043
Coffee shop land use	-0.744	0.318	-0.693	0.400	0.051	0.863	116.301	0.390
Multi-use development	-0.079	0.207	-0.078	0.218	0.001	0.018	98.222	0.986
Within 1 mi. of a university	-0.311	0.283	-0.359	0.220	-0.048	-1.058	76.149	0.293
Constant	-0.491	0.110	-0.460	0.081	0.031	1.763	73.636	0.082

The results of this t-test indicate that the new coefficient of the multi-use development indicator variable remained nearly the same as in the former model, and that the Smart-Growth Factor, coffee shop indicator, and university indicator did not change significantly. The office land-use indicator and the constant were the only variables to change significantly with a 90% confidence interval. These results suggest that the original model is relatively robust.

However, the lower goodness-of-fit of the original model re-estimated with the expanded data set prompted us to explore new model specifications. Indicator variables were created for each of the new land uses in the expanded data set to reflect the wider range of land uses in the Portland data. All of these indicator variables were then introduced into the model using a backwards stepping process (shown in Table 9). (It should be noted that one restaurant site from the original analysis had not formerly been assigned as a restaurant, but instead was assigned to an “other” group as there were too few restaurant sites to warrant a specific indicator. A restaurant indicator variable was created in the new specification, and that one site from the original analysis was added to the restaurant group.)

The new model has an improved adjusted R^2 value compared to previous models, and all variables are significant with at least a 95% confidence threshold. This model excludes the university indicator variable, which was not significant at any reasonable level of confidence. However, this variable was included in the original model to provide accurate and unbiased parameter estimates and so was added to this model to produce the final model, shown in Table 10. This model explains a very similar amount of variation (adjusted R^2 = 0.486) as the above models, and all variables aside from the university indicator and the intercept are significant at a 95% confidence level.

Table 9. Backwards Regression Model

Dependent Variable = Natural Logarithm of Ratio of Actual Peak Hour Vehicle Trips to ITE-Estimated Peak Hour Vehicle Trips			
	New PM Model		
Model Variables	**Coefficient**	**t-statistic**	**p-value**
Smart-Growth Factor (SGF)	-0.28	-4.171	6.23E-05
Office land use (1 = yes, 0 = no)	-0.77	-3.747	2.92E-04
Coffee shop land use (1 = yes, 0 = no)	-1.21	-3.758	2.80E-04
Residential land use (1 = yes, 0 = no)	-0.47	-3.093	2.53E-03
Multi-use development (1 = yes, 0 = no)	-0.61	-3.313	1.26E-03
Convenience Store land use (1 = yes, 0 = no)	-1.14	-8.117	9.18E-13
Drinking Place (1 = yes, 0 = no)	-1.01	-5.340	5.33E-07
Constant	0.00	0.033	0.97
Overall Model			
Sample Size (N)	114		
Adjusted R^2-Value	0.485		
F-Value (Test value)	16.231 ($p \approx 0$)		

Table 10. Backwards Stepwise Model with added University Indicator Variable

Dependent Variable = Natural Logarithm of Ratio of Actual Peak Hour Vehicle Trips to ITE-Estimated Peak Hour Vehicle Trips			
	New PM Model		
Model Variables	**Coefficient**	**t-statistic**	**p-value**
Smart-Growth Factor (SGF)	-0.24	-3.299	0.001
Office land use (1 = yes, 0 = no)	-0.85	-3.900	1.70E-04
Coffee shop land use (1 = yes, 0 = no)	-1.20	-3.727	3.14E-04
Residential land use (1 = yes, 0 = no)	-0.48	-3.197	0.002
Multi-use development (1 = yes, 0 = no)	-0.62	-3.357	0.001
Convenience Store land use (1 = yes, 0 = no)	-1.12	-7.975	1.99E-12
Drinking Place (1 = yes, 0 = no)	-0.99	-5.249	8.03E-07
Within 1 mi. of a university (1 = yes, 0 = no)	-0.19	-1.089	0.278
Constant	0.03	0.35	0.727
Overall Model			
Sample Size (N)	114		
Adjusted R^2-Value	0.486		
F-Value (Test value)	14.375 ($p \approx 0$)		

4. Validation of New Model

The 27 sites that were excluded from the data set used to estimate the above models were used to validate the final model shown in Table 10. The results of this validation can be seen in Figure 6.

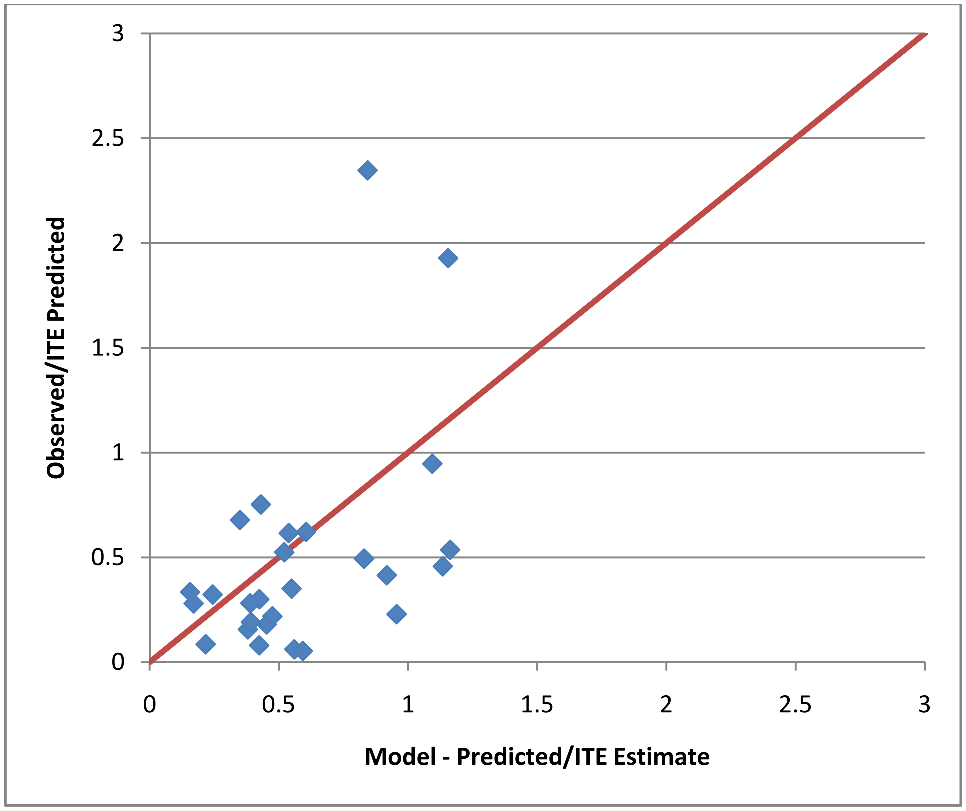

Figure 6. Observed versus Predicted Ratios to ITE Estimates: Validation Sites

The model performs well in general, though the model tends to over-predict trips (as indicated by points below the diagonal line in Figure 6). Two notable outliers are in the restaurant category (a Laughing Planet Cafe and a Hot Lips Pizza in the Ecotrust Building). A possible explanation for these outliers is that the ratio of actual to ITE-estimated trips does not vary as strongly with smart growth characteristics for this land use. This limitation was also seen in Clifton et al. (2012) where only 58% of restaurant validation sites were closer to the actual trip rate than the ITE estimate. Here 88% of the model estimates for restaurant sites are closer to the actual than are the ITE estimates, whereas overall 96% of the model estimates are closer than the ITE estimates.

There are a number of important considerations in this analysis, including the appropriateness of combining sites from Portland and California. Additionally, certain land uses varied more drastically than others. In some intermediate models that included the restaurant land-use indicator variable, this variable had a positive coefficient, which stems from the fact that restaurants included in the sample had vehicle trip rates higher than the ITE estimates on average. Further work to account for unmeasured variables is needed to address this problem. This work and further efforts will better quantify the effects of smart growth characteristics on trip rates, and in doing so inform practitioners of how to better estimate potential vehicle trip rates from smart growth sites.

5. Conclusions

This report chronicles follow-up work done on the original California-based Smart Growth Trip Generation (SGTG) model developed by Schneider et al. (2013b). It combines the original data set with one collected in the Portland Metro Area by Clifton et al. (2012) to verify the original model, re-estimate a new model, and validate the new model based on a set aside subset of data. Verification results showed that the original model successfully predicted the number of vehicle trips better than the ITE estimate in 75% of Portland sites that most closely met the criteria for applying the original model. The model re-estimation effort increased the goodness of fit while incorporating more sites to create a more robust model that is a applicable over a wider range of site characteristics. Finally, the validation section showed that the new model performed well for a diverse set of 27 sites in California and Oregon.

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