Background and Overview of
Validation of Potential Smart Growth Trip Generation Methodologies

for the California Smart Growth Trip Generation Rate (SGTGR)
Methodology and Validation Subcommittees
(prepared by Rick Lee – July 28, 2010)

Overview

As we have seen, most traffic studies conducted in California base their estimates of development impacts on the Institute of Transportation Engineers' *Trip Generation* manual, or on the San Diego Association of Governments' (SANDAG) similarly constructed *Traffic Generators*. The ITE *Trip Generation Handbook* (a companion volume to *Trip Generation*), describes procedures for adjusting the manual's vehicle trip generation rates to account for the effects of mixed use development, based on limited data. While neither the ITE manual nor the handbook present validation data of their reported rates and equations, they do describe procedures for collecting traffic generation data at developed sites in order to validate, refine or replace the published rates.

The methods that are being studied (or possibly developed) by the SGTGR effort differ substantially from conventional ITE trip-generation methods. In order to provide practitioners with substantiation of the validity of the methods and their estimates, the study team plans to compare results of each potential method against empirical traffic data gathered at developed smart growth sites within California. Site identification is underway, and data collection will hopefully begin under separate contract by early 2011 (if the recession subsides sufficiently to allow data collection).

The study team is also using traffic count data already available from the EPA and SANDAG studies for 10 of the California sites that was used to evaluate these agencies' versions of the MXD method. These sites include one in Northern California (in Sacramento), three in Orange County, and six in San Diego County. A limitation of this existing set of data is that it includes vehicle trips only; also it does not report peak hours in some cases.

The SGTGR evaluation process (whether using pre-existing or new data) will be to compare the empirical data collected at each site to estimates produced by the various "candidate" methodologies for that site. Key steps the UCD project team anticipates conducting in this approach are as follows:

1. Calculate each site's ITE gross trip generation based on: a) the reported ITE average trip rates, and b) the reported ITE trip generation equations. (i.e., summing the trips from the individual land use categories). Also apply the ITE Handbook's multi-use internal capture rates equation for mixed-use sites.
2. Identify each candidate method's needed input variables on a consistent basis for each validation site.
3. For all candidate methods, compute the estimate of external vehicle trip generation, and compare to both the gross and multi-use ITE trip generation estimates to the cordon traffic counts for the site.
4. The study team and Methodology Subcommittee may consider possible refinements to the candidate methodologies to improve the validation against the empirical traffic count data, or may decide to develop a new methodology if no existing methodologies are sufficiently accurate.

This approach represents a substantial advance over the approach taken in the existing ITE trip generation guidelines. The methodologies tested in this study will be validated via comparison of method estimates against the best available empirical field data gathered from a range of case study sites. When the validation process is completed, it will help select or devise a new analysis technique for traffic engineers that can more accurately and defensibly quantify impacts and size infrastructure for smart growth development projects.

The remainder of this document summarizes the "validation" approach taken by three key prior tool development projects: the EPA MXD spreadsheet, the SANDAG MXD spreadsheet, and the finalized NCHRP 8-51 report *Enhancing Internal Trip Capture Estimation for Mixed-Use Developments.*

I. EPA MXD Spreadsheet Validation Approach (based on the draft *Research-Based National Method of Estimating Trip Reduction Attributable to Multi-Use Development Research Report,* US EPA, n.d.)

The EPA MXD spreadsheet model was applied to 16 multi-use developments (MXDs) in various parts of the US for which counts of external vehicle trips were available AND which were not one of the 239 mixed-use sites used to develop the underlying equations. Seven of these sites are in Florida: six of these Florida sites are described in Appendix C of the ITE Trip Generation *Handbook*, and the seventh is the new neo-traditional town of Celebration, Florida. Six of the remaining sites are located in northern and southern California, and the remaining three are in Texas and Georgia; cordon counts at these last three sites were originally conducted for the NCHRP 8-51 study (see below).

Overall, the EPA validation sites are comprised of mixed-use developments and areas ranging in size from approximately 5 acres to over 1,000 acres. The sites represent a wide range of densities, land use mixes, and development scales. Populations of the validation MXDs range from zero (Crocker Center in Boca Raton, FL, containing commercial and office uses only) to nearly 17,000 (the entire town of Moraga, CA). Employment levels range from near zero (in The Villages in Irvine, CA) to more than 6,000 (Jamboree Center in Irvine, CA). Some sites are well served by transit, including one built around a rail station. Others are located in suburban areas and are poorly served by transit. The diversity of the comparison sites suggests that a tool that matches all would help establish its validity for analyzing a wide variety of projects.

Data were collected for all model variables for each of the 16 sites. The variables “Employment within one-mile” and “Employment within 30 minutes by transit” were estimated from regional travel models, and verified from aerial photos. Some of the site data was confirmed from development websites. Trip purpose percentages were estimated based data presented in NCHRP Report 365 for the combination of land uses contained within each MXD.

These validation tests produced two types of performance measures: root mean squared error (RMSE) and pseudo R-squared. RMSE is a measure of the percentage by which the trip generation estimates produced by the method deviate from the actual trip generation counted at each of the study sites. The lower the RMSE deviation, the more accurate is the prediction method. R-squared is a measure of how well the prediction method accounts for the degree of variation in trip generation from one site to another, An R-squared of 0.5 indicates the method explains 50 percent of the variation among cases and a value of 1.0 would imply a perfect ability to capture the variation in trips from one site to another.

Among the validation sites, use of the EPA Mixed-Use Method produced a significantly better root mean squared error (RMSE) and pseudo-R squared than traditional methods when comparing estimated to observed external vehicle trips. Estimates from the ITE *Trip Generation* manual had an RMSE of 40 percent and pseudo-R squared of 0.58, and modified estimates using ITE's current trip internalization techniques had an RMSE of 32 percent and pseudo-R squared of 0.73. Estimates produced by the Mixed-Use Method had an RMSE of only 26 percent and pseudo-R squared of 0.82. This means that the Mixed-Use Method explains roughly 82 percent of the variation in trip generation among the 16 sites, with the remaining 18 percent attributable to variables not included in the method.

II. VALIDATION of the EPA MXD METHOD for SAN DIEGO SITES (Based on *Trip Generation for Smart Growth, Final Report*, SANDAG, 2010)

To evaluate the EPA MXD method (referred to as the Mixed-Use Method in this section) for use in the San Diego region, a series of tests were performed comparing the method’s estimations with actual traffic count data from a number of sites within the region. This included comparisons at both large designated Smart Growth Opportunity Areas (SGOAs, defined below) and six smaller mixed-use and TOD sites.

Smart Growth Opportunity Areas. The SANDAG Smart Growth Concept Map identifies a list of SGOAs classified into one of seven place types (Metropolitan Center, Urban Center, Town Center, Community Center, Rural Village, Mixed-Use Transit Corridor, and Special Use Center). SANDAG identified a list of 57 existing SGOAs to be studied in this analysis. These 57 SGOAs were chosen by virtue of having residential and employment densities on the ground that currently meet the prescribed thresholds

Analysis of SGOAs. For most of the SGOAs, obtaining traffic counts entering and exiting the areas was not feasible due to the size of the SGOAs and the inability to filter out through trips. An alternative method to cordon counts was therefore identified.

Fehr & Peers (consultant to SANDAG) used available data from the *SANDAG Regional Household Travel Behavior Survey* (conducted mainly in 2006) to collect observed trip reduction percentages, which could be compared to the Mixed-Use Method's predicted trip reduction percentages. SANDAG staff provided Fehr & Peers with a data set of "flags" identifying which trips from the survey began and/or ended in one of the SGOAs. The trip data also included travel modes and travel party sizes. From this information, the total number of origins, destinations, and internalized trips (trips that begin and end in the same SGOA) by auto, walk, bicycle, and transit modes was computed for each SGOA. This was translated into observed values of probability of a trip being Internal, or external Walk/Bike, or Transit, the three key outputs of the Mixed-Use Method.

The analysis was performed for each of the twenty SGOAs that had at least 100 trips recorded in the survey. A cutoff of 100 trip records was chosen because in general, a sample size of at least 30 to 40 for each probability being estimated (i.e., the probability of a trip being either 1) internal; 2) external Walk/Bike; or 3) external Transit) is necessary for meaningful sample probabilities that are close to their true values.

Vehicle trip reduction at the SGOAs studied averaged 24 percent relative to raw trip calculations using SANDAG trip rates, ranging from as high as 47 percent in downtown San Diego to 32 percent in North Park/City Heights, and as low as 5 percent in Mira Mesa. Overall, the Mixed-Use Method proved to be a conservative predictor of trip reduction, underestimating trip reduction by about 10 percent on average, but the estimated and observed trip reductions are highly correlated.

Smaller Mixed-Use/TOD Sites. Six additional smaller mixed-use/TOD sites were identified for comparing the Mixed-Use Method estimates to actual counts of vehicles entering and exiting each site. The sites were selected from a list of developments representing typical smart development mixes and density in the region. The sites are all cohesive developments rather than historic neighborhood, because so as to be more representative of new development. Sites were also selected to be as consistent as possible with ITE data collection recommendations, e.g. the ability to identify and count all vehicular access/egress points.

The six sites selected and counted were as follows:

1. Station Village at Rio Vista Trolley Station, bounded by Camino Del Este, Rio San Diego Drive, Qualcomm Way, and the trolley tracks (residential and retail; trolley station and local bus)
2. La Mesa Village Plaza, bounded by La Mesa Boulevard, Acacia Avenue, Orange Avenue, and the train tracks (residential, retail, and office; trolley station)
3. The Uptown Center in the Hillcrest neighborhood, bound by University Avenue, Cleveland Avenue, Richmond Street, Washington Street, and SR-163 (residential & retail; high frequency local bus)
4. The Village at Morena Linda Vista Trolley Station, bound by Morena Boulevard, Linda Vista Road, Napa Street, and the train tracks (residential and retail; trolley station)
5. Hazard Center, bound by SR-163, Friars Road, Frazee Road, and Hazard Center Drive (retail and office; trolley station)
6. Heritage Town Center at Otay Ranch in Chula Vista, bound by Santa Rita Street, Palomar Street, Santa Andrea Street, and the southern end of the parking lot, not including the houses on Fieldbrook Street (residential, retail, and medical office).

A set of maps were created illustrating the sites' locations and driveways where traffic counts were made. Continuous 24-hour traffic counts were conducted at the six small mixed-use/TOD sites on typical midweek weekdays: Tuesday, Wednesday, or Thursday. Counts were conducted in October of 2008 for Otay Ranch, and in May and early June of 2009 (prior to the end of the K-12 school year) for all other sites.

Analysis: Small Mixed-Use/TOD Sites With Counts. For the small mixed-use/TOD sites, preliminary estimates of site trip generation were calculated from *San Diego Traffic Generators* trip rates and site land uses. These estimates of raw trips use suburban trip generation rates for single use sites and do not consider the effects of mixed-use development or transit access. The Mixed-Use Method was applied to each site and the trip reduction percentages were applied to the raw trips to obtain Mixed-Use Method net trips. SANDAG staff provided site land uses and values for most of the Mixed-Use Method input variables.

The results of the small sites analysis suggest that the Mixed-Use Method is an excellent predictor of external vehicle trips generated by smart growth development, tending to be slightly conservative, but without overestimating smart growth trips to the same degree as conventional trip generation methods. At all six sites, the Mixed-Use Method results in an estimation of external vehicle trips that is below the levels of estimated trip

generation using raw trips alone and at or above the level of trips that was determined through actual counts. On average, the *San Diego Traffic Generators* trip generation rates for suburban development overestimate traffic from the six sites by 29 percent, while the Mixed-Use Method reduces the average overestimate to 9 percent.

In the study of the six small SANDAG sites some of the input variables were determined by estimation methods, as follows:

- Due to confidentiality restrictions associated with California Employment Development Department data, employment levels for some sites were not always reflective of current land uses in the SANDAG databases; in those cases, they were determined from the building areas and jobs per 1,000 square foot conversion ratios.

- VRPA Technologies performed an independent set of land use data checks, collecting data from traffic studies wherever possible, and estimated building occupancy. Those estimates were taken into account in the calculation of raw trips.

- Vehicle ownership per capita was calculated from 2000 Census data using the census block group(s) that most closely matched the sites' locations. SANDAG staff estimated employment within 30 minutes by transit using their regional travel demand model.

III. VALIDATION of the NCHRP 8-51 Estimation Procedure (Based on pending NCHRP 8-51 Final Report Appendix F)

The NCHRP 8-51 estimation procedure was applied to seven different developments for which at least land use information, peak hour cordon counts, and proximity information were available. Four of these developments provided data for this study; the other three did not. The validation test was to see how well the estimation procedure could begin with ITE trip generation data and reproduce the external vehicular cordon volumes. Five of the developments had directional cordon traffic volumes available for both peaks. These developments included:

- Mockingbird Station (Dallas, TX)
- Legacy Town Center (Plano, TX)
- Atlantic Station (Atlanta, GA)
- Crocker Center (independent site, Boca Raton, Florida), and
- Mizner Center (independent site, Boca Raton, Florida).

Two developments had only non-directional PM peak period counts available. They were:

- Boca del Mar (FL) and
- Southern Village (independent site, Chapel Hill, North Carolina).

The validation test compared four different estimation methods to determine which method produced the results closest to the cordon counts:

- the estimator described in the NCHRP 8-51 report,
- the estimator, but without a proximity adjustment,
- the existing ITE multi-use estimation method, and
- unadjusted ITE trip generation.

Development data and approximations of surveyed mode split and vehicle occupancies were input to the estimation procedure.

Figures F-1 through F-4 (that follow) show the comparisons of vehicle trips for both AM and PM peak periods and both inbound and outbound directions.

In Figure F-1, it is evident that for the AM peak hour inbound vehicle trips, the NCHRP estimation methods—both with and without the proximity adjustment—produce the best results for three of the five developments; the current ITE multi-use method is closest for one site and slightly better than the NCHRP method for another site. Atlantic Station is more closely estimated by both unadjusted trip generation and the current ITE multi-use method. The current ITE multi-use method is better than raw trip generation, but the method developed in this project is even closer to the counts.

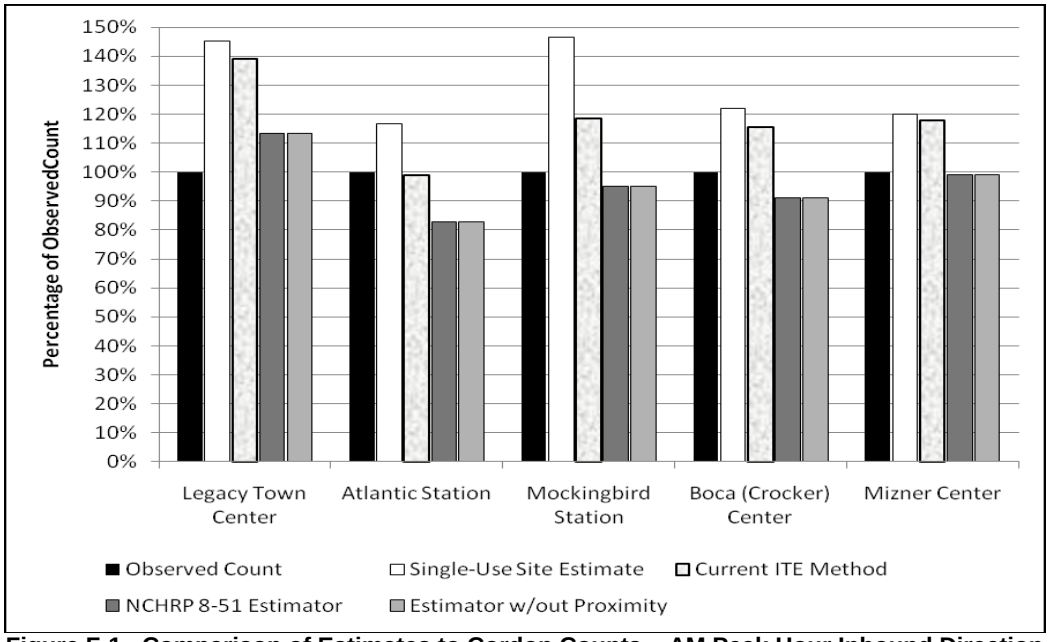

Figure F-1. Comparison of Estimates to Cordon Counts – AM Peak Hour Inbound Direction

Figure F-2 shows similar results for AM peak hour outbound vehicle trips with the recommended estimator (both with and without the proximity adjustment) producing the best results for four of the five developments. This time Mizner Center is better estimated by raw trip generation and the current ITE method. As with the previous comparison, the ITE multi-use method is an improvement on raw trip generation.

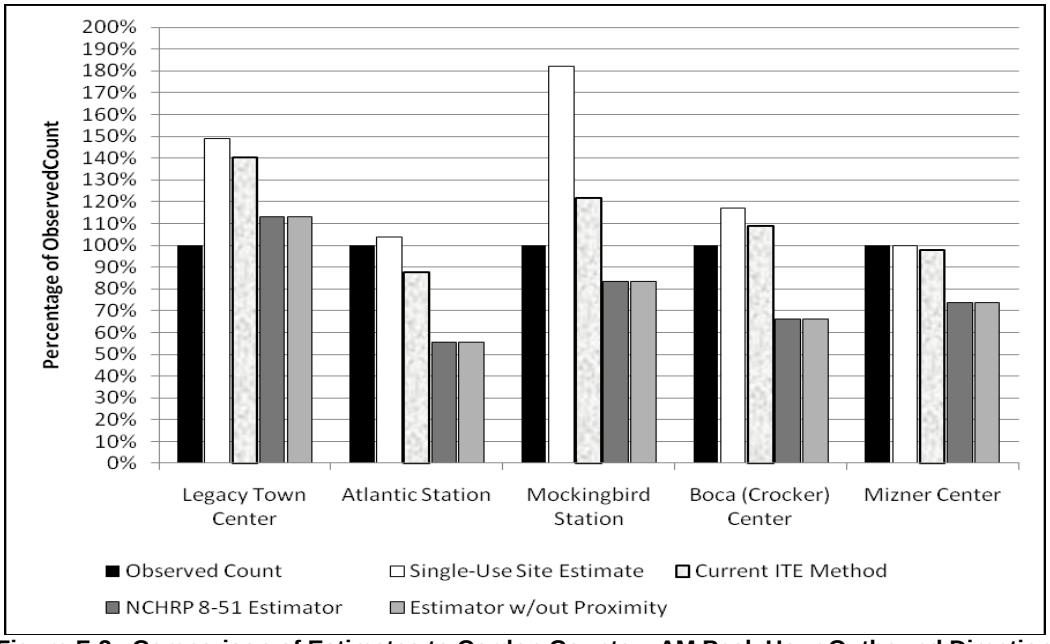

Figure F-2. Comparison of Estimates to Cordon Counts – AM Peak Hour Outbound Direction

The PM inbound comparison in Figure F-3 shows that the NCHRP method with the proximity adjustment produces the closest estimates for two sites, with the methods with and without proximity about equal for the two sites, and the raw ITE trip generation closest for one site. Again, Mizner Center was better estimated by another method (this time raw trip generation), but the other four are best estimated by the recommended method.

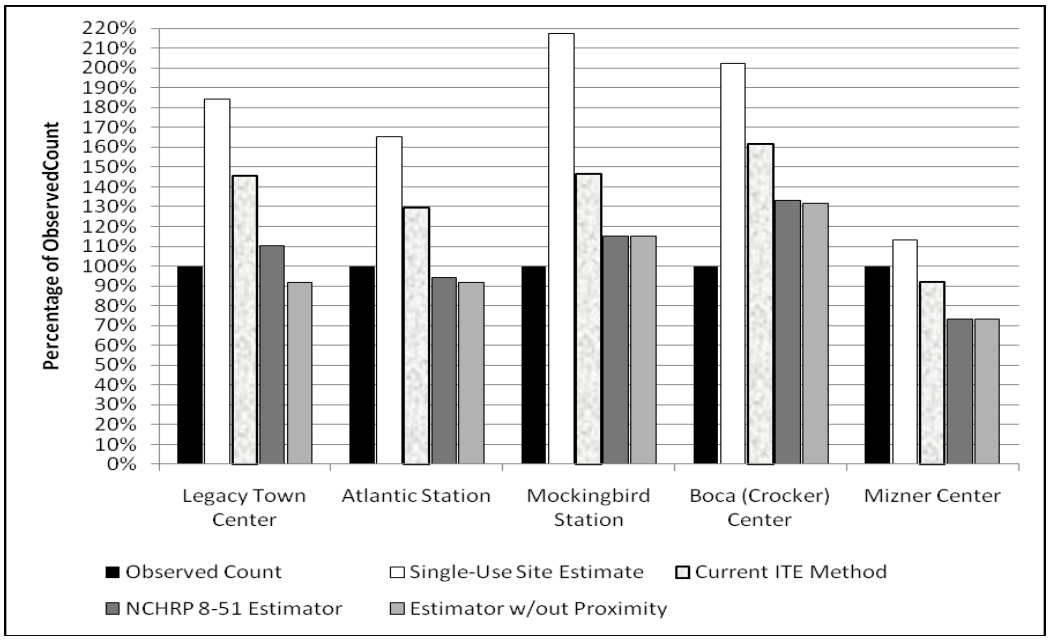

Figure F-3. Comparison of Estimates to Cordon Counts – PM Peak Hour Inbound Direction

Figure F-4 shows the comparison for PM peak hour inbound trips. As for the other time periods and directions, one or the other of the NCHRP 8-51 methods produces the closest estimates in four of the five cases. The methods with and without proximity adjustments are each best for one MXD while both yield approximately the same results for two MXDs. In this case, Boca Center is better estimated using the existing ITE method.

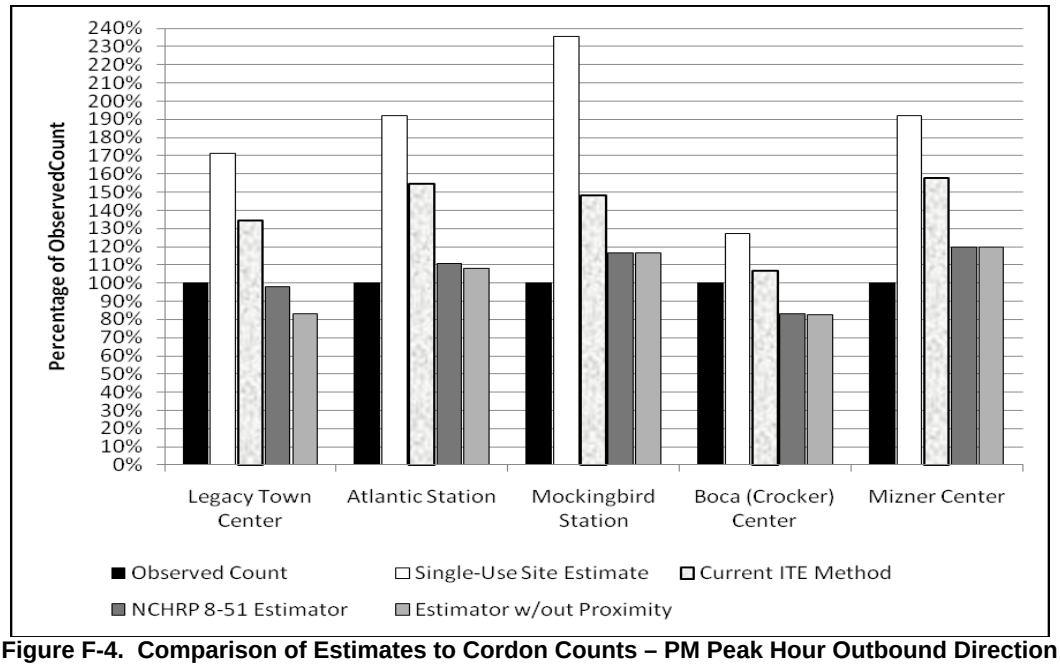

Figure F-4. Comparison of Estimates to Cordon Counts – PM Peak Hour Outbound Direction

In total, the recommended method—with or without the proximity adjustment—produces more reliable estimates for four of the five developments.

The results for the other two developments—Boca del Mar and Southern Village—show two different patterns. For Boca del Mar, both the existing ITE and recommended methods produce significantly low estimates, but are closer than the recommended method without proximity adjustments or the ITE method. The raw estimate is above the actual external count, but it and the ITE method are the closest of the estimates (about 4 percent closer than the recommended method with proximity adjustment). For Southern Village, the results are very different. The recommended method (both with and without proximity adjustments) produce estimates very close to the counts.

Table F-3 (note this is the original table number in the NCHRP 8-51 report) may quantify the degree of accuracy or error more clearly, recognizing that the statistics presented represent the sum of combined results. The average error shown is the simple sum of the percent deviations from the counts as derived in Table F-2. On average, as a group the estimates all exceed the counts (for example, the recommended method with proximity adjustment is an average of 4 percent). This is very misleading and not relevant for single developments, because overestimates and underestimates tend to cancel each other out. What may be of value in those percentages is that they could result in the sum total trip generation of several developments in an area. However, that is not what is being validated here.

More applicable is the absolute average error, which is the sum of the magnitudes of the errors averaged over the five developments. This shows more clearly what deviations—above or below actual—were found. Clearly, by examining the figures and Table F-3, it is easy to determine that the raw trip generation greatly overestimates external vehicle trip generation for the validation sites. The existing ITE method is a major improvement from raw trip generation. The recommended NCHRP 8-51 method brings the estimates significantly closer to actual. (Note that the difference between the actual and absolute value of the errors shows that there are both overestimates and underestimates occurring.)

Table F-3. Comparison of Error Statistics

Error Type	**Raw ITE Trip Generation**	**Existing ITE Multi-use Method**	**Recommended NCHRP 8-51 Method**		**Explanation**
			With Proximity Adjustment	No Proximity Adjustment	
Average error	+55%	+26%	-4%	−7%	Average error for sum of all sites
Absolute average error	55	28	17	17	Average magnitude of error per site
Standard deviation	68	34	20	19	Expect two-thirds of site estimates within this error range

The standard deviation shown in Table F-3 better represents the estimated probable magnitude of error that might occur using these estimation methods. Again, the relative magnitudes of error among the methods place them consistently in the same order.

It is clear that the NCHRP 8-51 recommended method provides more accurate estimates. Since the existing ITE multi-use adjustment method was developed from data from three of the six developments that were also used in this NCHRP project, the recommended method can only be viewed as being a further improvement.

The standard deviations for the recommended NCHRP 8-51 method, both with and without proximity adjustment, are about 20 percent of the actual external inbound and outbound volumes. This is less than the variations in the raw ITE nondirectional trip generation rates for the component land uses. For example, for the land uses listed in Table F-1, the standard deviations for their AM and PM peak hour trip generation rates are all in excess of 50 percent of the mean.

Not clear, however, is whether or not the proximity adjustment adds any current value. The validation results show no significant statistical benefit from the proximity adjustment. It has sufficient data only for the PM peak period (and less of that than would be desired). There is no AM proximity adjustment recommended at this time. On the other hand, the only examples for which the results were better without the proximity adjustment was when both variations of the new method were overestimating. In all cases the proximity adjustment either has no significant effect or renders the estimate more conservative (higher).

Conclusions Regarding Validation of the NCHRP 8-51 Method

The validation supports two principal findings:

1. The recommended method does produce noticeably more accurate results than either raw ITE trip generation estimates from the ITE *Trip Generation* report or the existing method described in the *Trip Generation Handbook*. This is true with or without the proximity adjustment.

2. The proximity adjustment, available at this time for the PM peak period, tends to make slightly more conservative estimates but overall does not, at this time, improve accuracy over a group of estimates. It can produce significant effects for larger developments.