American Planning Association
Planning Advisory Service
Creating Great Communities for All

November/December 2020

PAS MEMO

Still Getting Trip Generation Right: Revalidating MXD+

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When planners are tasked with analyzing a proposed mixed use land development project, an early step in the process is to determine the number of trips it would generate during peak hours and on a daily basis. The Institute of Transportation Engineers' *Trip Generation Manual* (ITE 2017) is the default national resource for estimating a site's vehicle trips.

The vast majority of trip generation data within the ITE manual, however, was collected at suburban locations (Figure 1). As a result, direct application of this resource to analyze mixed use projects situated in dense, urban settings will almost certainly result in an overestimation of the site's vehicular trip generation.

This could have many secondary, undesired consequences, such as oversizing a project's infrastructure needs, overpayment of traffic impact fees, overestimation of vehicle miles of travel (VMT) and by extension greenhouse gas emissions, oversupply of parking, and other effects. In fact, the *Trip Generation Handbook* itself states, "The application of suburban data in dense or multimodal urban settings can in some cases overestimate motor vehicle demand" (ITE 2017, 8).

Transportation planners have known this for a very long time. In fact, it was the impetus for the May/June 2013 *PAS Memo*, "Getting Trip Generation Right: Eliminating the Bias Against Mixed Use Development." This *PAS Memo* is a long overdue update to the 2013 *PAS Memo*. It documents how the mixed use trip generation model known as MXD+ was recalibrated and revalidated using recent observed travel activity at a diverse group of mixed use sites located throughout the United States. This recalibration is necessary given the myriad changes in mobility, technology, and societal behavior that have occurred since MXD+ was originally formulated in the late 2000s.

This updated version of MXD+ represents a more accurate means for estimating a site's external vehicle trips than other available methods. Planners are encouraged to use state-of-the-practice analytical methods such as MXD+ to accurately estimate a mixed use project's trip generation. Because MXD+ can be a key part of the land-use development and environmental review process, it is important that it be available for planners to use. The last section of this *PAS Memo* describes how planners may access and apply this tool on their projects.

Figure 1. Data from autocentric suburban areas is not accurate for estimating trip generation from mixed use development projects. Photo courtesy Fehr & Peers.

A History of MXD+

The Urban Land Institute's *Mixed-Use Development Handbook* (Schwanke 2003) defines mixed use development as having three or more integrated and compatible land uses interconnected by on-site infrastructure that supports active transportation (i.e., walking and biking). These types of projects are designed to encourage internal trip-making by non-automobile modes. When placed near transit and in urban areas, their residents, customers, and employees are more likely to walk, bike, or take transit to external destinations, rather than drive.

In the late 2000s, two separate research studies improved the state of practice regarding prediction of trips from mixed use projects. Studies sponsored by the U.S. EPA (MXD) and the Transportation Research Board (NCHRP 684) developed separate tools for improving trip generation estimates for mixed use developments. The MXD model was originally derived from 239 mixed use sites across the country and was validated in 2009 against 22 sites. *NCHRP 684: Enhancing Internal Trip Capture Estimation for Mixed use Developments* (Bochner et al. 2011) was based on six well-known mixed use project sites.

The principal authors of these original two methods—Reid Ewing at the University of Utah, Brian Bochner at Texas A&M, and Jerry Walters at Fehr & Peers—decided to collaborate on an integrated method that captured the best of both sets of research findings. The result was MXD+. The 2013 *PAS Memo* referenced above describes how MXD+ performed better than either individual method when validated against 27 sites. According to Table 3 of that *Memo*, MXD+ achieved average errors of two percent, 12 percent, and four percent for daily, AM peak hour, and PM peak hour conditions, respectively. These values suggest a good fit between the model's estimation and the actual counts.

Excluding the unprecedented changes in travel and economic distress that have occurred in 2020 because of the COVID-19 pandemic, there have been sweeping changes in travel behavior in the nearly 10 years since MXD+ was originally validated. These include:

- **E-Commerce.** More goods and services are now routinely delivered directly to the home because of the convenience of internet shopping. The number of daily freight deliveries per person in the United States increased from about 0.12 in 2009 to 0.25 in 2018 (Humes 2018).
- **Ridehailing.** Transportation network companies (TNCs) such as Uber and Lyft did not exist when MXD+ was originally validated, but they are now nearly ubiquitous throughout the country. Travel by TNC generates both an inbound and outbound trip, whereas a private passenger vehicle would have generated a single trip end. A 2018 report summarizing TNC user survey results found that 60 percent of TNC trips would have otherwise been taken by walking, bicycling or transit, or not taken at all (Shaller 2018). This further suggests that in geographic areas where travel by TNC is common, they may be contributing to increased vehicle trips.
- **Telecommuting.** Nationwide, the proportion of employees working from home rose from 4.1 percent in 2010 to 5.7 percent in 2019 (ACS 2010, 2019). With vastly improved technology, many professional sector employees can now routinely work from home and avoid the work commute, as seen during the COVID-19 pandemic in 2020.
- **Micromobility.** Bikeshare, e-scooters, and microtransit are now found in urban areas across the United States. These travel options have shifted some trips away from driving and transit, though they also create "first mile/last mile" opportunities to connect to transit.
- **Decreased transit ridership.** After peaking in 2015, overall U.S. transit use has been steadily declining in the vast majority of urban areas. Bus ridership numbers are now at their lowest since the early 1970s, light rail numbers are declining, and commuter rail ridership levels have leveled off in the last several years (National Academies of Sciences, Engineering, and Medicine 2020). These declines may be partially explained by some of the factors described above.
- **Evolving land uses and changing trip generation rates.** The *Trip Generation Manual, 10th Edition* (ITE 2017) contains sizeable decreases in vehicle trip generation rates for nearly all types of employment land uses when compared against the *Trip Generation Manual, 9th Edition* (ITE 2012). This is due to the replacement of pre-2000 data used in the *9th Edition* with new data collected after 2010. The *10th Edition* also includes several new land-use categories (i.e., fast casual restaurant), more overall data, and better definitions for land uses often found in mixed use sites such as multifamily housing.

Given these factors, it is readily apparent that a recalibration of MXD+ is warranted based on a dataset that considers these trends in travel behavior.

Model Recalibration

The development of predictive models requires two main steps: calibration and validation. *Calibration* refers to creating the "model fit" based on a set of observational/experimental data. *Validation* refers to how that fitted model then performs (in terms of accuracy of predictions) against an independent dataset that was not used to calibrate the model. The following sections describe how these two processes were followed for the update of the MXD+ model.

Model recalibration consisted of a series of sequential steps: site selection, data collection, initial calibration results, and recalibration.

Site Selection

The following selection criteria were established to guide the selection of sites for data collection and analysis:

- Sites should be geographically diverse, both in terms of locations across the United States and in their place type.
- Sites should be both small and large, with varying levels of mode choice options.
- Site traffic should be able to be accurately counted at a reasonable cost.
- Sites should be well understood in terms of occupied land uses, available modes of travel, and other built environment characteristics.

Since MXD+ is intended to be applied across a variety of geographic settings, it was important that the chosen sites represented the most common place types where studies are typically conducted. Hence, site selection focused on suburban and urban settings and avoided rural areas and ultra-dense areas where auto mode split is very low.

Land-use mix was of paramount importance in the selection of validation sites. A diverse, complementary mix of uses on site was desired so that the internal trip estimates of MXD+ could be tested. For instance, a project consisting of 1,000 dwelling units and a mere 5,000 square feet of office/retail would not be a good candidate site as the actual trip rate for the dwelling units would be more important than all other factors combined.

It was critical to select sites that allowed for accurate data collection. This resulted in the exclusion of potential sites because of non-project-related cut-through traffic passing through the site and adjacent on-street parking and loading/unloading activity.

Site selection also considered whether an accurate estimate of occupied land-use quantities could be developed. In most instances, this was achieved from public agency staff, developer input, project site plans, or internet searches. In some instances, it was necessary to measure building footprints using aerial imagery and conduct research on vacant and available dwelling units and commercial square footage. This process is similar to the standard procedure used to document existing land uses for travel demand model development purposes.

A total of 15 sites were chosen for data collection. These sites were then separated into either the calibration dataset (12 sites) or validation dataset (3 sites). The validation sites were specifically selected to provide a diverse range of geographic settings, modal opportunities, and project sizes to challenge the accuracy of the model over a wide array of conditions.

Early analysis findings indicated that model accuracy could be improved for weekday AM and PM peak hour conditions through a set of minor adjustments, which are discussed in detail below.

Figure 2 shows the 12 calibration sites that were selected, as well as the three validation sites. Notably absent are any locations within the Midwest, Rust Belt, New England, Texas, and Florida. Several well-known candidate sites in Texas (e.g., Mockingbird Station in Dallas) and Florida (e.g., Mizner Park) were considered but rejected because of challenges in data collection accuracy and cost. The lack of certainty of occupied land-use totals and availability of other required input variables were further barriers to selection.

Data Collection

Table 1 (p. 3) provides an overview of the size, diversity of uses, and transit proximity of the sites that comprise the calibration database.

The MXD+ tool includes queries from various sources (e.g., U.S. Census, American Community Survey, local travel demand models) to enable easy importing of built environment and surrounding area travel characteristics and demographic variables. Some of the more important variables are:

- Employment within a one-mile walk distance
- Percentage of regional employment within a 30-minute transit ride
- Site/adjacent area intersection density (a proxy for site walkability and internal trip-making potential)

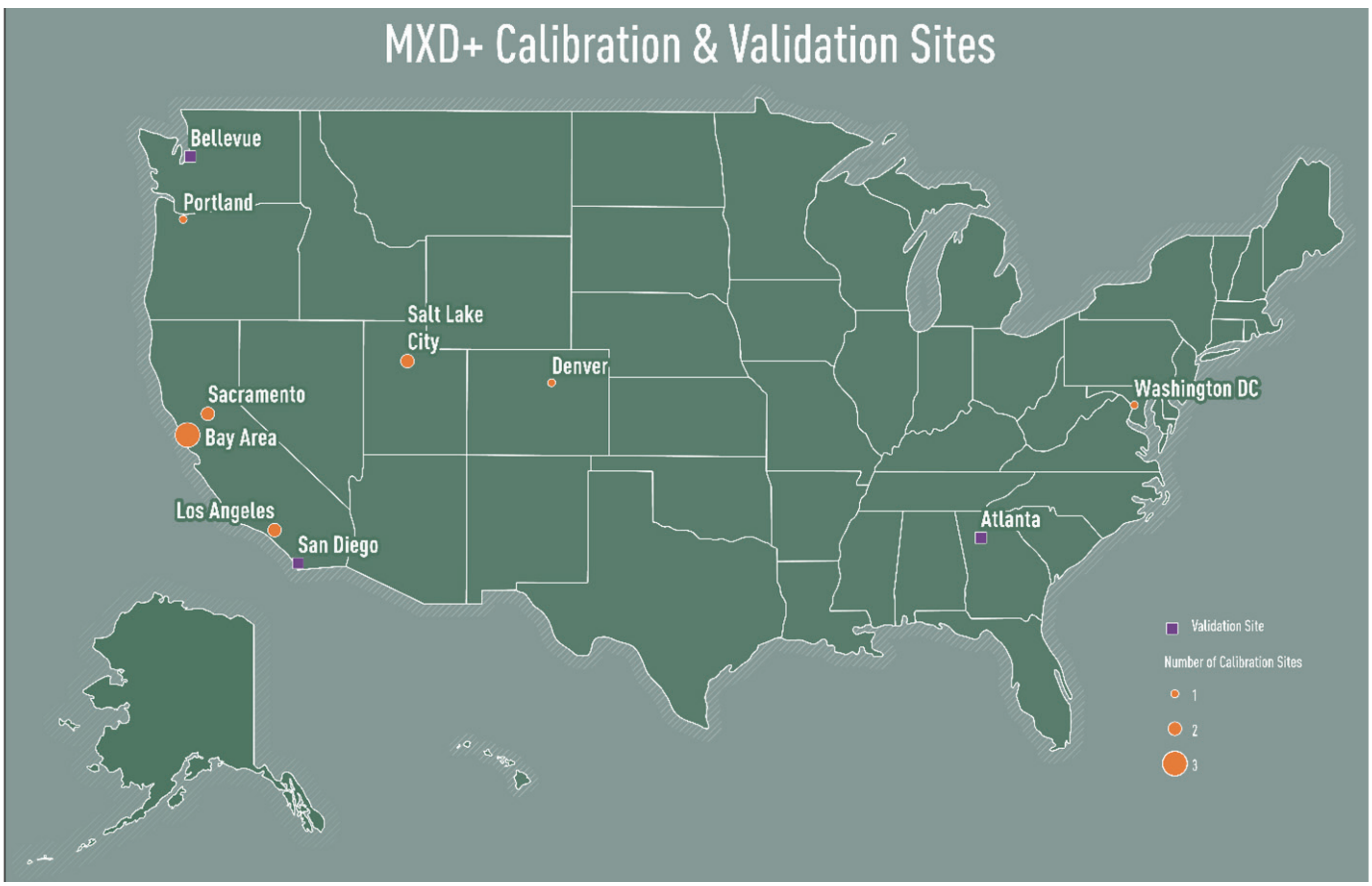

Figure 2. MXD+ calibration and validation sites. Courtesy Fehr & Peers.

Table 1. Overview of MXD+ Calibration Sites

Metric	*Range*	*Average*	*Median*	*Total*
Acres	4–221 acres	50 acres	19 acres	603 acres
Number of Dwelling Units[1]	8–1,841 units	563 units	414 units	6,756 units
Retail	0–753,000 sq. ft.	168,000 sq. ft.	38,000 sq. ft.	2,013,000 sq. ft.
Office	0–1,084,000 sq. ft.	212,000 sq. ft.	41,000 sq. ft.	2,544,000 sq. ft.
Range of Transit Services	None, adjacent bus stops, on-site transit centers, and nearby/on-site light rail			
Range of Land Uses	Grocery store Student housing Medical office building Restaurants Health club	Pharmacy Hotel Coffee shop Library Schools	Museum Movie theater Bowling alley Hospital	

1. Over 95 percent of dwelling units are multifamily. Site with only 8 dwelling units also includes 315 student housing units.

- Average vehicle ownership per household
- Average household size

Measurement of all types of vehicle trips generated by each site was a critical component of the data collection effort. This includes the following distinct types of trip generation:

- Vehicles being parked on site (either in a surface lot or garage)
- Motorists parking on the street and then walking into the site
- Persons being dropped off or picked up by a taxi, TNC, or friend/spouse/coworker to access the site
- Truck/service deliveries to the site (either parked on site
- or from a loading zone)

To overcome the considerable cost associated with data collection via video cameras, an innovative approach was undertaken: collection of a site's travel during its busiest 14 hours was used to accurately estimate its 24-hour traffic generation. Typically, these 14 hours represent about 90 percent of the land use's total daily trip generation. A factoring process was then performed using the ITE hourly trip generation data (from the *Trip Generation Manual*) to convert the 14-hour counts into 24-hour observations.

In several instances, site characteristics allowed for a multi-day hose tube count in which a pneumatic tube placed across the road registered vehicles as they passed over. But this was the exception and not the norm as the majority of sites were located in dense, urban environments where tube counts would have likely yielded inaccurate results.

In several cases, site reconnaissance was necessary to better understand site-specific travel behavior. This led to conclusions that on-street parking on one side of the street was project-related, while the other side was not. Other situations involved motorists parking in nearby garages or lots and walking into the project. In those instances, pedestrian activity (both at intersections and mid-block) was observed and classified to translate pedestrian groups into vehicle trips.

Seven of the 12 calibration data sites were counted in October 2019. The remaining five were counted as part of prior research efforts, in either 2015 or 2017. Table 2 shows the number of vehicle trips these sites were observed to generate on a weekday daily basis and during the AM and PM peak hours.

Table 2. Trips Generated by MXD+ Calibration Sites

Time Period	*External Vehicle Trips[1]*		
	Range	*Average*	*Median*
Weekday (daily)	2,383–35,825	12,461	9,495
Weekday AM peak hour[2]	100–2,017	752	518
Weekday PM peak hour[3]	181–3,381	1,161	712

1. *Includes trips to/from the site for all purposes including deliveries, TNC trips, pass-by trips (i.e., already on the adjacent street) in addition to the typical trip types.*
2. *AM peak hour represents the site's busiest consecutive 60-minute period of travel between 7 and 9 a.m.*
3. *PM peak hour represents the site's busiest consecutive 60-minute period of travel between 4 and 6 p.m.*

Recalibration of MXD+

The land-use and built environment variables described above were inputted into MXD+ for each of the 12 calibration sites. MXD+ then processed that data in the following generalized steps:

- **Step 1:** Gross number of vehicle trips were estimated for land uses based on published rates contained in the *Trip Generation Manual, 10th Edition*.
- **Step 2:** Built environment and site characteristics variables were used to estimate the likelihood for internal trip-making and external trips being made by transit and walking/biking.
- **Step 3:** The model estimated the number of internal trips made between complementary land uses within the site.
- **Step 4:** The model estimated the number of external trips made by transit and walking/biking.

MXD+ relies on *Trip Generation Manual, 10th Edition* trip generation rates (both weighted averages and as derived from fitted curve equations) for the "suburban/urban" land use category. The "rural," "multi-use urban," and "center city core" categories are not used because their corresponding datasets have insufficient numbers of sites from which reliable trip generation rates could be derived.

Because trip generation estimates should reflect, to the extent possible, the specific uses within the project's zoning classification (ITE 2017, 14), individual uses such as grocery stores, banks, pharmacies, restaurants, health clubs, day-care centers, and others present at each site were entered separately into MXD+ versus being aggregated into a single "retail shopping center" category.

Early analysis findings indicated that model accuracy could be improved for weekday AM and PM peak hour conditions through a set of minor adjustments. While the daily results were sufficiently accurate so as to not require any adjustments, the AM and PM peak hour predictions tended to underestimate the observed count more often than desired. This was an undesirable outcome because MXD+ applications should be reasonably conservative. If anything, they should err on the side of overestimating actual trips. The means by which internal trips and external non-automobile trips had been estimated for AM and PM peak hour conditions was quickly identified as a leading culprit.

In the MXD+ model, the following steps are applied to estimate reductions in AM and PM peak hour vehicle trips due to internal trip-making and external walk/bike trips.

- **Step 1:** Apply MXD peak hour factors by trip purpose to the daily predicted probabilities of these trip reductions to obtain AM and PM peak hour percentages.
- **Step 2:** Apply the following weighting of two methods that independently estimate these trip reductions:
  - ❍ **PM Peak Hour:** 37 percent NCHRP 684 and 63 percent MXD
  - ❍ **PM Peak Hour:** 37 percent NCHRP 684 and 63 percent MXD

The NCHRP 684 procedure was incorporated by ITE into its *Trip Generation Handbook*, and is referred to as the "ITE Internalization Method" in this PAS Memo. Note that this procedure estimates internal trips only for AM and PM peak hours (and not daily conditions).

Data from the 2017 National Household Travel Survey was found to yield a set of peak hour factors for the MXD component of this calculation (Step 1 above) that much better fit the calibration dataset when compared against those used originally in the EPA MXD version. These values, shown in Table 3, were used to update the model. This is the one change that was needed to update the 2013 MXD+ model for 2020.

Calibration for Daily Conditions

The calibration tests focus on five specific areas (from least to most statistically complex): aggregate total trips comparison, proportion of cases where MXD+ underestimates the actual number of trips, absolute average error, correlation coefficient, and percent Root Mean Square of Errors (RMSE). Results are presented first for daily conditions, and then for AM and PM peak hour conditions.

Aggregate Total of MXD+ Estimates Versus Actual Counts

For the 12 sites, MXD+ estimated 160,696 daily external vehicle trips. This represents seven percent more trips than the 149,527

Table 3. Updated MXD Peak Hour Factors by Trip Purpose[1]

Predicted Probability[2]	*AM Peak Hour*			*PM Peak Hour*		
	HBW[3]	*HBO[4]*	*NHB[5]*	*HBW[3]*	*HBO[4]*	*NHB[5]*
Internal capture	1.10	1.80	1.00	1.00	1.00	1.00
Walking/biking external	1.20	1.30	1.00	1.00	1.00	1.00
Transit external	1.40	1.10	1.00	1.40	1.00	1.00

1. Source was analysis of data from the 2017 National Household Travel Survey, specifically analyzing the national dataset to under stand the relative likelihood of each type of travel choice during weekday AM and PM peak hours, versus on a daily basis.
2. These factors are multiplicatively applied (by trip purpose) to the daily predicted possibilities for each type of vehicle trip reduction.
3. HBW = Home-based work trip.
4. HBO = Home-based other trip (e.g., shopping, school, recreation, etc.).
5. NHB = Non-home-based trip (e.g., from office to deli).

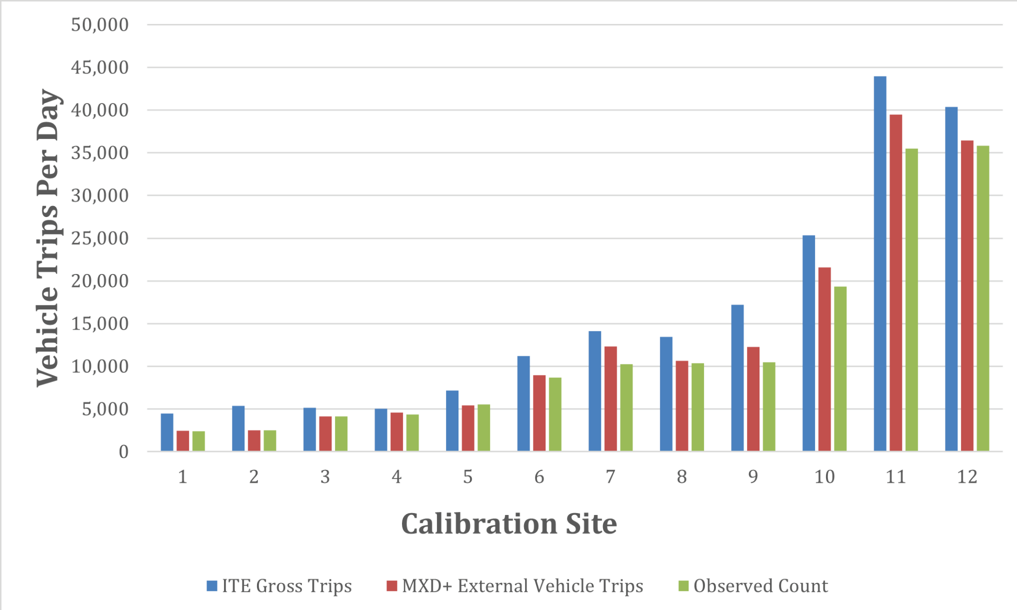

Figure 3. MXD+ calibration for daily conditions. Courtesy Fehr & Peers.

daily trips that were counted. This implies that MXD+ is being reasonably conservative.

The ITE gross daily trip estimate (i.e., without any reductions of internal trips or external non-auto trips) total for the 12 sites was 192,905 trips, which represents a 29 percent overestimation versus the counts. This reiterates the statement from the *Trip Generation Handbook* that the use of ITE rates for the suburban/urban place type without any adjustments for internal trips and external non-auto trips would result in a substantial overestimation of a mixed use site's vehicle trip generation.

Proportion of MXD+ Underestimations

At all 12 sites, the MXD+ estimates were slightly higher than or very closely matched the observed count. At one site, an underestimate of two percent was predicted, though condition was considered insignificant as daily traffic volumes can fluctuate by five percent or more from day to day. In summary, MXD+ results displayed a very low likelihood of underprediction.

Average Absolute Error

Figure 3 orders the 12 calibration sites from least to greatest number of observed daily trips. Data is then presented for the MXD+ external vehicle trip estimate and the ITE gross trip estimate. At sites 1–6, MXD+ predictions are nearly identical to the observed counts. Slightly greater variation occurs at the larger sites (7–12) for reasons discussed below.

The 12 sites displayed an average absolute error of six percent, meaning that this MXD+ estimate was, on average, within six percent of the actual count. For the six sites with the smallest number of actual trips (i.e., no more than 8,700), the performance was substantially better with the average absolute error being just two percent. For the six sites with the greatest number of total estimated trips, the average absolute error was 11 percent.

The larger sites presented some unique challenges. At one site, the majority of its uses were retail-related, many of which are believed to be underperforming based on the types of tenants. Even when the "department store" land-use category was applied (which has lower rates than the shopping center category), MXD+ still overestimated trips.

Another site consisted of a number of vacation rental-type properties whose occupancy could not be determined at the time of the counts in October 2019. Additionally, this site had a public street passing through it. Although traffic flows were collected at each end and evaluated to determine likely amounts of cut-through travel along it, this type of situation is not ideal and may have contributed to the differences between the observed and estimated vehicle trip values.

Correlation Coefficient

This statistic measures the relationship between variables. A measure close to 1.00 means that variables are highly positively correlated, a value of zero suggests no or weak correlation, and a value close to 1.00 represents strong negative correlation.

The correlation coefficient was 1.00 between the MXD+ external daily trip generation estimates and observed counts. A value of 0.88 or higher is generally desirable for travel demand model development.

Percent RMSE

RMSE—the square root of the mean squared error between the predicted and observed count divided by the mean of the observed count—is a measure of the model's accuracy. Large errors can have a substantial effect on percent RMSE; thus, it is sensitive to outliers. Percent RMSE should not be compared across different data sets (i.e., daily versus peak hour) because they are scale dependent. In general, the closer the value is to zero, the more accurate the model.

Table 4. MXD+ Calibration Results

Calibration Statistic	*Goal/Objective*	*Daily*	*AM Peak Hour*	*PM Peak Hour*
Aggregate total of MXD+ vehicle trip generation estimates versus actual counts	As close to zero as possible	+7%	-0.9%	+1.6%
Proportion of calibration sites that were underestimated by MXD+[1]	Ideally none	0 of 12	4 of 12	3 of 12
Average absolute error	As close to zero as possible	6%	11%	6%
Correlation coefficient	> 0.882	1.00	0.99	1.00
Percent RMSE	< 40%[2]	12%	13%	7%

1. Estimates that were within five percent of the actual counts were not considered underestimations since traffic volumes themselves may fluctuate by five percent or more from one day to the next.
2. Based on statistical measures typically applied in travel demand model development.

The percent RMSE was 12 percent. A value of 40 percent or less is considered reasonable for travel demand model development.

Calibration for AM and PM Peak Hour Conditions

Table 4 displays the five calibration statistics for AM and PM peak hour conditions. Results are also shown for daily conditions for comparison purposes.

Overall, Table 4 indicates that MXD+ does an excellent job of fitting the data for AM and PM peak hour conditions. However, there were some specific instances where MXD+ was challenged to accurately match the observed counts.

At one site in Southern California, MXD+ overestimated AM peak hour trips by 12 percent, but underestimated PM peak hour trips by 14 percent. This mixed use site contained a large quantity of office space, and it is possible that site-specific tenants or atypical employee commute patterns may have contributed to the AM peak hour overestimation. During the PM peak hour, a disproportionately high amount of on-street parking and loading/unloading activity was observed (for which each vehicle is counted twice), which is likely associated with TNCs. Since MXD+ does not directly account for higher-than-average levels of TNC use in more urbanized areas, off-model adjustments would be necessary to account for that behavior. At another calibration site, the traffic counts were performed by students in 2015, and did not fully capture all trips to the project, resulting in underestimations of actual trips during both peak hours.

Validation of MXD+

Three case study sites were selected for validation purposes. These sites were specifically chosen to provide geographic diversity, varied sizes, and widely differing levels of modal travel options.

Safeway/Avalon, Bellevue, Washington

Safeway/Avalon is a true mixed use center, totaling four acres with a variety of complementary land uses (Figure 4). It consists of a midrise apartment complex known as Avalon Meydenbauer with 368 occupied units, a 55,000 square-foot Safeway grocery store, 15,000 square feet of general retail, and 8,000 square feet of sit-down restaurants. It is situated in downtown Bellevue, across Lake Washington from downtown Seattle. Despite its location only 10 miles from downtown Seattle, a commute to downtown by auto can exceed one hour.

Sound Transit operates fixed-route bus service with stops immediately adjacent to the building. The site is located in a suburban downtown setting with good sidewalk connectivity and heavy pedestrian volumes, but also wide arterial streets, large blocks, and heavy traffic. There are no bike routes or lanes nearby.

Adjacent land uses include a variety of residential, retail, and employment centers as well as a large regional mall and the 21-acre Downtown Park. Apartment residents pay $85 to $110 per month for a parking space.

Figure 4. Safeway/Avalon. Photo courtesy Fehr & Peers.

Table 5. Safeway/Avalon Validation Site Trip Generation Comparison

Source of Estimate	*Daily*[1]	*AM Peak Hour*[1]	*PM Peak Hour*[1]
Field measurements in October 2019	5,505	239	512
MXD+ external vehicle trip generation	5,968 (+8%)	254 (+6%)	497 (-3%)
Unadjusted ITE trip rates	8,580 (+56%)	437 (+83%)	798 (+56%)
ITE Trip Rates with ITE Internalization Method	Not Available	359 (+50%)	577 (+13%)

1. Values in parentheses represent the percent increase/decrease in trips estimated by the given method versus the 2019 field measurements.

Table 5 presents the number of external vehicle trips measured at this site in October 2019 versus the estimated number it would generate using MXD+. These results indicate that MXD+ yields a desirable result in which the site's external vehicle trips generation have been slightly overestimated (on a daily basis and during the AM peak hour). MXD+ underestimated the site's actual PM peak hour trip generation by 15 trips, which is very respectable given the 515 trips the site generated.

On a daily basis, MXD+ estimated a relatively modest four percent internal trips, but a much more substantial 34 percent external trips made by non-auto modes. These results make sense because the internalization will be limited by the types of uses present (i.e., no professional office). The site is well-served by transit and within the downtown part of Bellevue where there are thousands of jobs within a one-mile walk.

Table 5 also shows estimated AM and PM peak hour trip generation using unadjusted ITE *Trip Generation Manual* trip rates and the ITE Internalization Method for suburban/urban areas. The results show that the former would have overestimated the project's actual trip generation by 198 AM peak hour trips and 286 PM peak hour vehicle trips, a massive overestimate of what was measured. The latter would have overestimated that site's actual trips by 120 vehicles during the AM peak hour and 65 trips during the PM peak hour. This case study clearly indicates that MXD+ more accurately predicts the Safeway/Avalon site's actual vehicle trips than the standard ITE methods.

Hazard Center, San Diego, California

Hazard Center is located five miles north of downtown San Diego near the intersection of Interstate 8 and State Route

Figure 5. Hazard Center. Photo courtesy Fehr & Peers.

Table 6. Hazard Center Validation Site Trip Generation Comparison			
Source of Estimate	*Daily[1]*	*AM Peak Hour[1]*	*PM Peak Hour[1]*
Field measurements in October 2019	11,189	680	930
MXD+ external vehicle trip generation	12,395 (+11%)	696 (+2%)	977 (+5%)
Unadjusted ITE trip rates	15,588 (+39%)	966 (+42%)	1,367 (+47%)
ITE Trip Rates with ITE Internalization Method	Not Available	604 (-11%)	957 (+3%)

1. Values in parentheses represent the percent increase/decrease in trips estimated by the given method versus the 2019 field measurements.

163. It is a vibrant, highly diverse mixed use center comprising 16 acres. It consists of a midrise apartment complex with 120 dwelling units, 256,000 square feet of office space, a 305-room hotel, a 7-screen movie theater, 23,000 square feet of sit-down restaurants, and 111,000 square feet of general retail. Retail uses at the time of data collection included cleaners, dance studios, bookstores, financial offices, salons, learning centers, fitness studios, coffee shops, jewelers, auto detailing, and optometry. All land uses are situated within a quarter-mile walk to the Hazard Center light rail station, which serves the San Diego Trolley Green Line light rail service (Figure 5, page 8). This station transports riders to downtown San Diego in about 20 minutes. A bus stop is also situated within a quarter mile of the site.

A variety of uses are within a half-mile walk from Hazard Center, including Westfield Mission Valley Mall, grocers, employers, and restaurants, and the San Diego River multiuse pathway is adjacent to the site. In summary, this site has a good mix of complementary land uses, regional transit access, and various nearby uses that can be accessed by walking or biking.

Table 6 presents the number of external vehicle trips measured at this site in October 2019 versus the estimated number it would generate using MXD+. The MXD+ results were significantly closer to actual counts as compared to both standard ITE trip generation methods as well as the ITE Internalization Method alone. The former overestimated counts by an average of six percent, while the unadjusted ITE trip rates overestimated counts by an average of 42 percent, and the ITE Internalization Method both over-and underestimated the actual peak hour counts.

Similar to the findings from the Bellevue site, for this site MXD+ yields a desirable result in which the site's external vehicle trip generation has been slightly overestimated during all three analysis periods. Reasons for this overestimation could be the result of many factors such as the type of office tenants, levels of occupancy at the hotel during the count period, and relative success of the various retail uses on site (note that the site is surrounded by many other competing retail centers). This offers a great illustration of how challenging it can be to accurately estimate a site's trip generation.

Figure 6. Avalon. Photo courtesy Google Earth.

Avalon, Alpharetta, Georgia

Avalon is a suburban mixed use project of a quintessential type now found in many communities across the country. At a considerable size of 79 acres, it features all of the typical land uses found in mixed use sites plus some additional atypical uses, such as single-family residential. It is a food and beverage destination with numerous bars and restaurants ranging from fast food, fast casual, and high-turnover sit-down to fine dining establishments.

Avalon consists of 100 single-family dwelling units, 525 multifamily dwelling units, 582,000 square feet of office space, a 330-room hotel, a 12-screen movie theater, a 45,000-square-foot grocery store, 250,000 square feet of general retail, and 54,000 square feet of restaurant space (Figure 6).

The project is located directly west of U.S. Highway 19, about 25 miles north of downtown Atlanta. Adjacent transit is limited to a single local bus route that operates on 30-minute headways. Parking is not priced anywhere within Avalon, with the exception of the hotel. The site is anchored by Avalon Boulevard, a 1,200-foot long, walkable "Main Street" flanked by ground-floor retail and stacked residential on both sides. Lower-density residential, office, and parking extends outwardly from the site's hub, with vehicular access provided by 10 distinct driveways on two public streets.

Table 7. Avalon Validation Site Trip Generation Comparison

Source of Estimate	*Daily*[1]	*AM Peak Hour*[1]	*PM Peak Hour*[1]
Field Measurements in October 2019	33,301	1,685	2,543
MXD+ External Vehicle Trip Generation	33,332 (0%)	1,894 (+12%)	2,674 (+5%)
Unadjusted ITE trip rates	38,406 (+15%)	2,387 (+42%)	3,505 (+38%)
ITE Trip Rates with ITE Internalization Method	Not Available	1,461 (-13 %)	2,203 (-13%)

1. *Values in parentheses represent the percent increase/decrease in trips estimated by the given method versus the 2019 field measurements.*

Unlike the previous two case studies, adjacent land uses are suburban or rural in nature. To the north and west of the site is a residential wooded area. To the east is U.S. Highway 19. To the south are various buildings containing employers, restaurants, and a trade college, though they are separated from the site by the six-lane Old Milton Parkway.

Table 7 presents the number of external vehicle trips measured at this site in October 2019 versus the estimated number it would generate using MXD+. The match is nearly perfect for daily conditions, with modest overestimations during the AM and PM peak hours. The overestimation during the AM peak hour is particularly noteworthy because ITE trip rates for restaurants reveal greater than expected (by most analysts) levels of trips generated by these uses than is typically seen. It is a shortcoming in this data resource, and one that becomes visible when large amounts of restaurant space are present.

On a daily basis, MXD+ estimated 8.5 percent internal trips, which makes sense based on the diversity of land uses on site, though the large amount of office ultimately limits internal trip opportunities. External trips made by non-auto modes were estimated at five percent, which is reasonable given the modest transit service provided and limited amount of uses within walking/biking distance of the site.

As was the case for the other two validation sites, application of unadjusted ITE *Trip Generation Manual* rates resulted in substantial overestimates of actual project trip generation, by as much as 42 percent. And had an analyst instead applied ITE trip rates with the ITE Internalization Method, the site's actual trips would have been underestimated by 13 percent during both the AM and PM peak hours. Not only would this approach have yielded less accurate results than MXD+, but the values themselves would have been underestimates, which is highly undesirable.

How Planners Can Use MXD+

This section describes how planners can use apply MXD+ on their projects using readily available information and tools. While the process is somewhat arduous (given the inherent complexity of the methodology itself), it is entirely possible to complete provided the analyst has access to various necessary inputs. The following steps will produce MXD+ results:

- **Step 1: Download the original MXD model** from the Fehr & Peers website's MXD+ page.
  This is the same model that resides on the EPA MXD website, but this version has been modified to reflect the peak hour factoring values from Table 3 of this *PAS Memo*.
- **Step 2: Download the ITE *Trip Generation Handbook* Internalization Method spreadsheet** from the ITE website.
- **Step 3: Enter/calculate project land uses, site characteristics, and trip generation estimates in each spreadsheet.** This step requires that the project›s trip generation be estimated using the ITE *Trip Generation Manual, 10th Edition* for the suburban/urban place type. Most agencies, planning organizations, and planning/engineering firms have access to this data.
- **Step 4: Apply the following blending of results from the two spreadsheets.**
  - Daily: 100% Modified EPA MXD
  - AM Peak Hour: 89.9 percent Modified EPA MXD / 10.1 percent ITE Internalization
  - PM Peak Hour: 63.5 percent Modified EPA MXD / 36.5 percent ITE Internalization

The source of these blending ratios is Table 1 of the 2013 *PAS Memo*. Note that the daily estimate is based entirely on the Modified EPA MXD spreadsheet because the ITE Internalization Method does not estimate internal trips for daily conditions.

Conclusion

Planners are at risk of severely overestimating a mixed use project's trip generation if they apply unadjusted ITE trip generation rates. As documented in published resources such as the *Trip Generation Handbook* and quantitatively demonstrated by the three validation sites described above, unadjusted ITE rates overestimated each site's actual vehicular trip generation by about 50 percent during weekday AM and PM peak hours.

ITE has attempted to address these inaccuracies by integrating the NCHRP 684 trip internalization methodology into its guidance. However, in terms of predictive ability, MXD+ performed much better than the ITE Internalization Method. For the three validation sites, MXD+ had an average error of seven percent during the AM peak hour, as compared with an average error of 25 percent for the ITE Internalization Method. During the PM peak hour, MXD+ had an average error of four percent, as compared with an average error of 10 percent for the ITE Internalization Method.

Planners are encouraged to use MXD+ not only because it provides a more accurate depiction of traffic impacts of a mixed use project, but also because it translates into more accurate estimations of VMT, greenhouse gas emissions, and air, noise, and energy impacts. This will help ensure that mixed use projects will not be burdened by unnecessary fees, excessive parking requirements, and other potential barriers to implementing projects that create more livable, sustainable communities.

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PAS Memo is a bimonthly online publication of APA's Planning Advisory Service. Joel Albizo, FASAE, CAE, *Chief Executive Officer; Petra Hurtado,* PHD, *Research Director; Ann F. Dillemuth,* AICP, *PAS Editor. Learn more at* planning.org/pas.

 PAS Memo *(ISSN 2169-1908) is published by the American Planning Association, which has offices at 205 N. Michigan Ave., Suite 1200, Chicago, IL 60601-5927, and 1030 15th St. NW, Suite 750 West, Washington, DC 20005-1503;* planning.org.