

Mixed Use Trip Generation (MXD)

Model Recalibration & Validation to 2019 Conditions

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This paper documents the recalibration and validation effort undertaken by Fehr & Peers in 2019–2020 of the MXD Tool. This revalidation was necessary given the myriad changes in mobility, technology, and societal behavior that have occurred since MXD was originally formulated in the late-2000's. This paper provides a straightforward “nuts and bolts” type description of this process.

MXD Model Origin

In the late-2000's, two separate research studies improved the state of practice regarding prediction of trips from mixed-use projects. Studies sponsored by the US 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 validated in 2009 against 22 sites. NCHRP 684: Enhancing Internal Trip Capture Estimation for Mixed-Use Developments (2011) was based on six well-known MXD 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. And thus, MXD was created. They published a paper entitled Getting Trip Generation Right: Eliminating the Bias Against Mixed-Use Development (American Planning Association, 2013). According to that paper, MXD achieved average errors of 2%, 12%, and 4%, for daily, AM peak hour, and PM peak hour conditions, respectively. These values suggest a good fit between the model's estimation and the counts.

Purpose/Need of Revalidation and Calibration

Excluding the unprecedented changes in travel and economic distress that have occurred in 2020 due to the COVID-19 Pandemic, there have been sweeping changes in travel behavior in the 10-plus

years since MXD was originally validated. Some of the many examples include increased e-commerce activity, the introduction of ridehailing (i.e., Transportation Network Companies (TNCs), such as Uber and Lyft), increased telecommuting, micromobility (e.g., bikeshare, e-scooters, and microtransit), increased auto ownership, and decreased transit ridership.

Additionally, in 2017, the Institute of Transportation Engineers (ITE) released the 10th Edition of the *Trip Generation Manual*. When compared to the 9th Edition (2012), the 10th Edition demonstrates sizeable decreases in vehicle trip rates for nearly all types of employment uses (due to the replacement of very old data with new data collected after 2010). It 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

Model Recalibration

Model recalibration involved site selection, data collection, and then calibration.

Site Selection

Fehr & Peers selected sites that were geographically diverse, both in terms of locations across the US, and as well as in their place type. They had varying levels of mode choice options, and their site trips were able to be accurately counted. The sites were well understood in terms of occupied land uses, available modes of travel, and other built environment characteristics. This diversity of use type, geographic placement, size allows for the model to be calibrated against a wider set of conditions versus an alternate approach where a more homogeneous set of sites were selected.

Consistent with standard practice in statistical analysis, the selected sites were divided into separate “calibration” and “validation” datasets. 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 later. The calibration dataset (12 sites) was used to determine the best fit provided by the adjusted set of factors. The validation dataset (4 sites), which was not included in the calibration dataset, were specifically selected to provide a diverse range of geographic settings, modal opportunities, and project sizes, which could be used to test the accuracy of the model. Those results are presented in case study format at the end of this paper.

Figure 1 shows the 12 calibration sites that were selected, as well as the four validation sites. Aside from the four case studies, individual site locations are not disclosed in this article because such information is not necessary to understand the data collection and analysis results. Case in point, transportation planners/engineers routinely use data from the *Trip Generation Manual*, which only discloses the states from which the data was collected. The traffic data collection did not require encroachment onto any private property to place cameras or hose tubes.

Data Collection

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

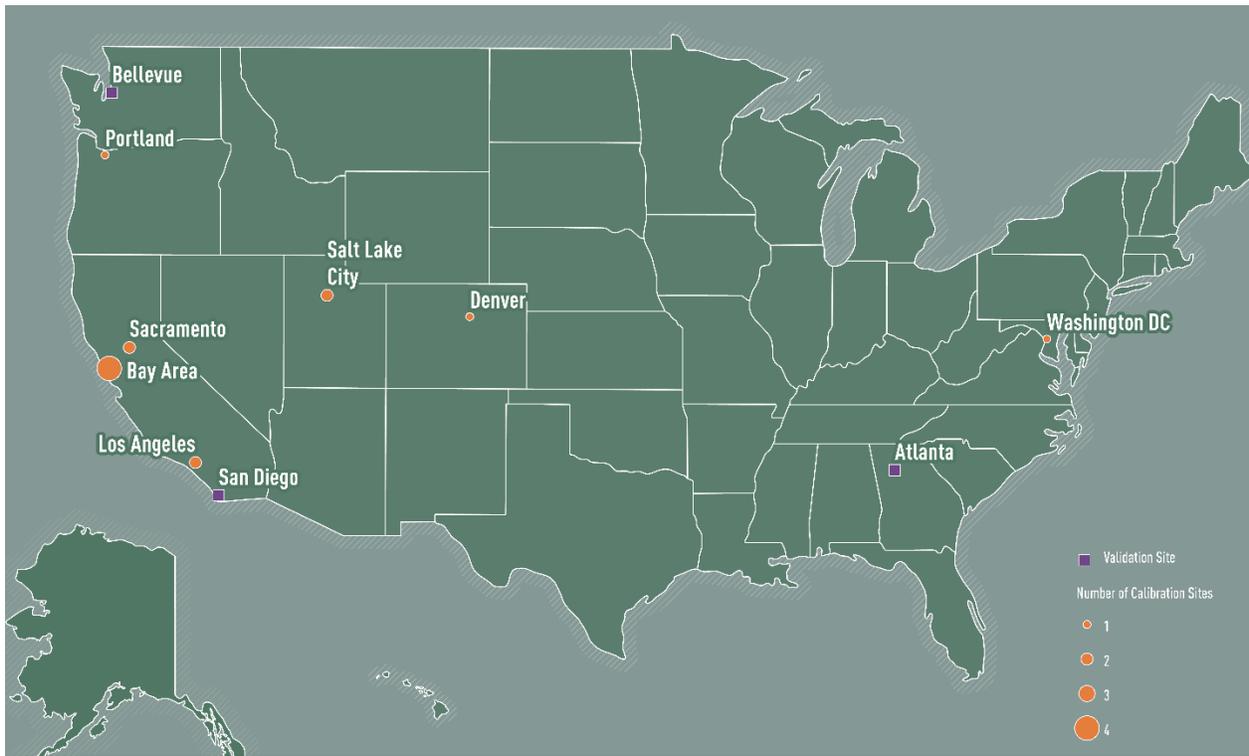


Figure 1: MXD Calibration and Validation Sites

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 street bus stops, on-site transit centers, and nearby/on-site light rail			
Range of Land Uses	<ul style="list-style-type: none"> ➤ Grocery Store ➤ Student Housing ➤ Medical-Office Building ➤ Restaurants 	<ul style="list-style-type: none"> ➤ Health Club ➤ Pharmacy ➤ Hotel ➤ Coffee Shop ➤ Library 	<ul style="list-style-type: none"> ➤ Schools ➤ Museum ➤ Movie Theater ➤ Bowling Alley ➤ Hospital 	

Notes: ¹Over 95% of dwelling units are multi-family. Site with only 8 dwelling units also includes 315 student housing units.

The average site was 50 acres and consisted of about 563 dwelling units (the vast majority being multi-family) and 380,000 square feet of non-residential space.

The MXD tool includes queries from various sources (e.g., US Census, American Community Survey, local travel demand models, etc.) 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, Percentage of regional employment within a 30 minute transit ride, and site/adjacent area intersection density (a proxy for site walkability and internal trip-making potential), and Average vehicle ownership per household.

Measurement of vehicle trips generated by each site was a critical component of the data collection effort. It was important that the data collection was comprehensive in terms of collecting all types of vehicle trips generated by each site (including project-related vehicles parking on-site or on-street, persons being dropped-off or picked-up by a taxi, TNC, or friend/spouse/coworker, and truck/service deliveries).

To overcome the considerable cost associated with data collection via video cameras, an innovative approach was undertaken whereby collection of a site's travel during its busiest 14 hours can be 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 (i.e., a pneumatic tube placed across a road that would register a vehicle as it passes over) to be performed. But this was the exception and not the norm since 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 is project-related, while the other side is not. Other situations involved motorists parking in nearby garages/lots and walking into the MXD. In those instances, pedestrian activity (both at intersections and mid-block) were observed and classified into groups to translate pedestrian groups into vehicle trips.

Seven (7) 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

Notes:

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 AM.

³ PM peak hour represents the site’s busiest consecutive 60-minute period of travel between 4 and 6 PM.

Recalibration of MXD

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

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

Nearly all data presented in the current *Trip Generation Manual* for the suburban/urban place type were collected at low-density, single-use, homogeneous developments with little or no public transit service, free parking, and little to no convenient pedestrian access. Hence, direct use of those rates for projects not aligned with those built environment factors are likely to result in an overestimation of vehicle trips. This statement, while obvious, is intended to set the stage for why gross ITE trip generation estimates (without any adjustments) substantially overestimate trips observed at the MXD sites.

The following guidance from Page 14 of the *Trip Generation Handbook* (Institute of Transportation Engineers, 2017) was used in the calibration process:

¹ MXD is programmed to include trip generation rates (both weighted averages and as derived from fitted curve equations) from the 10th Edition of the *Trip Generation Manual*. Data is input only for the “suburban/urban” land use category, and not for the “rural”, “multi-use urban”, or “center city core” categories because their corresponding datasets generally have insufficient numbers of sites from which reliable trip generation rates could be derived.

“The trip generation estimate should reflect, to the extent possible, the specific uses within the known or assumed generalized (using zoning) classification.”

Thus, individual uses such as grocery stores, banks, pharmacies, restaurants, health clubs, day-care centers, etc. present at each site were entered separately into MXD versus being aggregated into a single ‘retail shopping center’ category.

In reviewing the preliminary MXD results, it was concluded that the daily results were sufficiently accurate so as to not require any adjustments. But for AM and PM peak hour conditions, it was observed that MXD tended to underestimate the observed count more often than desired. This was certainly 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-auto trips were estimated for AM and PM peak hour conditions was quickly identified as a leading culprit.

The following describes the steps for how internal trips and external walk/bike trips for AM and PM peak hour conditions are estimated:

- **Step 1:** Apply the 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 the two methods that independently estimate these trip reductions:
 - AM Peak Hour: 10% NCHRP 684 and 90% MXD
 - PM Peak Hour: 37% NCHRP 684 and 63% MXD

An iterative statistical analysis was performed to determine which set of peak hour factors for the MXD component of this calculation best fit the data from the calibration dataset. The best fit values are shown in **Table 3**.

The *NCHRP 684* procedure has been incorporated by ITE into its Trip Generation Handbook, and is hence known as the “ITE with Internalization”. Note that this procedure estimates internal trips only for AM and PM peak hours (and not daily conditions).

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

Notes:

¹ Source was analysis of data from the 2017 National Household Travel Survey, specifically analyzing the national dataset to understand 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).

Transparency in calculations is one of the many objectives of MXD. By virtue of displaying these values here, it is possible for others to replicate MXD results, albeit through a substantial amount of data collection and analysis. The original MXD model (from 2011) is available for download from EPA’s website (<https://www.epa.gov/smartgrowth/mixed-use-trip-generation-model>), though it is noted that model does not include the latest land use categories, trip generation rates, and equations from the 10th Edition of the *Trip Generation Manual*. However, that model does form the basis for the daily module of MXD, but with these aforementioned adjustments added.

The calibration tests focus on the following five specific areas (from least to most statistically complex):

- Aggregate total trips
- Proportion of cases where MXD underestimates the actual number of trips
- Average absolute error
- Correlation coefficient²
- Percent RMSE³

Table 4 displays the five calibration statistics for daily, and AM and PM peak hour conditions, as well as the applicable statistical goal/objective for the given calibration statistic.

² This statistic measures the relationship between variables. A measure close to 1 means that variables are highly positively correlated; a value of zero suggests no or weak correlation, and a value close to -1 represents strong negative correlation.

³ This statistic is a measure of the model’s accuracy. It is the square root of the mean squared error between the predicted and observed count divided by the mean of the observed count.

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	> 0.88 ²	1.00	0.99	1.00
Percent RMSE	< 40% ²	12%	13%	7%

Notes:

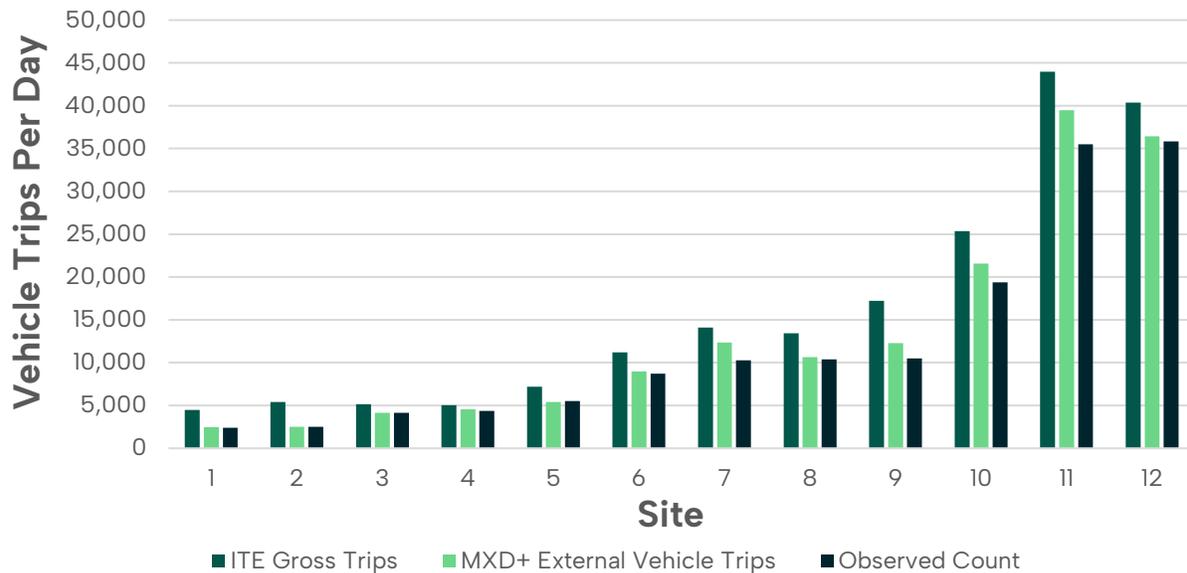
¹ Estimates that were within five percent of the actual counts were not considered underestimations since traffic volumes themselves may fluctuate by five percent or more from one day to the next.

² Based on statistical measures typically applied in travel demand model development.

Table 4 indicates that MXD does an excellent job of fitting the data for all three time periods. Challenges did however arise more frequently during peak hours versus daily conditions. Unique site specific conditions, such as their specific temporal commute patterns, degree of retail tenant success, and presence of TNCs contributed to some of these challenges.

Chart 1 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 (i.e., 7 – 12) for reasons discussed below.

Chart 1: MXD Calibration for Daily Conditions



For the 12 sites, MXD estimated 160,696 daily external vehicle trips. This represents 7% more trips than the 149,527 daily trips that were counted. This implies that MXD is being reasonably conservative.

If these sites had simply been analyzed using ITE gross daily trip estimates (i.e., without any reductions of internal trips or external non-auto trips), the resulting estimate would have been 192,905 daily trips, which is a 29% overestimation versus the counts. This reiterates prior research findings 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. This is acknowledged on page 8 of the *Trip Generation Handbook* by the following statement: “The application of suburban data in dense or multimodal urban settings can in some cases overestimate motor vehicle demand.”

For the 12 calibration sites, the reduction in daily trips caused by internal trip-making and external non-auto travel ranged from 10 to 50 percent, with average/median values near 20 percent. This large range is caused by a number of factors including: mix of land use, presence of transit, and site design, size, and geographic location.

Validation of MXD

Four case studies from across the US were selected for validation purposes. As noted previously, these sites were excluded from the calibration dataset in order to achieve the statistically desirable independent validation dataset. These sites were specifically chosen, as they are geographically diverse, are of widely varying sizes, and provide widely differing levels of modal travel options.

- Safeway / Avalon, Bellevue, WA** – This four-acre site is situated in downtown Bellevue, across Lake Washington from downtown Seattle. Despite being only 10 miles from downtown Seattle, a commute to downtown by auto can exceed over an 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 no bike routes/lanes nearby. Adjacent land uses include a variety of residential, retail, and employment centers as well as a large regional mall and the Downtown Park. Apartment residents pay \$85 to \$110 per month for a parking space.

- **Hazard Center, San Diego, CA** – is situated on 16-acres and located five miles north of Downtown San Diego near the intersection of Interstate 8 and State Route 163. All land uses are situated within a ¼-mile walk to the Hazard Center Light Rail Station, which serves the San Diego Trolley Green Line light rail service. This station transports riders to downtown San Diego in about 20 minutes. A bus stop is also situated within ¼ mile of the site. A variety of uses are within a ½-mile walk of the site including Westfield Mission Valley Mall, grocers, employers, and restaurants. The San Diego River multi-use pathway is situated adjacent to this site.
- **Avalon, Alpharetta, GA** – is a quintessential suburban mixed-use project now found in many communities across the country. At a considerable size of 79 acres, it features a vast array of land uses – all of the typical ones found in mixed-use sites plus some other atypical uses such as single-family residential. It is a food & beverage destination with numerous bars and restaurants ranging from fast-food, fast casual, high-turnover sit-down, to quality establishments. Avalon is located directly west of US 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. Adjacent land uses are suburban or rural in nature.
- **Southport, West Sacramento, CA** – is a very large (3,000 developed acres), established community situated directly west of downtown Sacramento. It features a wide array of land use types (i.e., residential, jobs, shopping, schools, etc.) often found in self-contained communities. Fixed route bus service is provided on main arterials within the community, and downtown Sacramento can be reached via a five-mile trip. It is geographically isolated from adjacent communities by the Sacramento River and shipping channels, allowing for its trips to be accurately counted via four gateways.

Table 5 displays the land uses present at each validation data site.

Table 5 – Validation Sites Land Uses

Site	Single-Family	Multi-Family	Office	General Retail ¹	Sit-Down Restaurants	Grocery Store	Hotel	Other/Note
Safeway / Avalon Bellevue, WA	-	368 du's	-	15 ksf	8 ksf	55 ksf	-	-
Hazard Center, San Diego, CA	-	120 du's	256 ksf	111 ksf	23 ksf	-	305 rooms	7-screen movie theater
Avalon Alpharetta, GA	100 du's	525 du's	582 ksf	250 ksf	54 ksf	45 ksf	330 rooms	12-screen movie theater
Southport, West Sacramento, CA	6,811 du's	893 du's	80 ksf	387 ksf	15 ksf	54 ksf	-	Elementary & High School, 600 ksf manufacturing

Notes:

¹Includes wide array of uses such as: cleaners, dance studios, bookstore, financial office, salon, learning center, jewelers, salons, auto detailing, optometry, etc. Banks, gas stations, fast-food restaurants, coffee shops, and fitness studios were estimated separately (based on their specific uses) but included in this land use total for reporting purposes.

du's = dwelling units. ksf = thousand square feet.

Table 6 presents the number of external vehicle trips measured at each validation site in October 2019 versus the estimated number it would generate using MXD. Footnote 2 in the table highlights an interesting phenomenon associated with the Southport validation case study. Because it is being validation at the gateways to entire community (versus essentially driveways for the other sites), it is necessary to subtract pass-by trips that would visit the retail uses, as those trips would not add traffic to the community gateways. Those values are shown in brackets.

Table 6 – Validation Sites Trip Generation Comparison

Site	Size	External Vehicle Trip Generation					
		Daily		AM Peak Hour		PM Peak Hour	
		October 2019 Count	MXD ¹	October 2019 Count	MXD ¹	October 2019 Count	MXD ¹
Safeway / Avalon Bellevue, WA	4 acres	5,505	5,968 (+8%)	239	254 (+6%)	512	497 (-3%)
Hazard Center San Diego, CA	16 acres	11,189	12,395 (+11%)	680	696 (+2%)	930	977 (+5%)
Avalon Alpharetta, GA	79 acres	33,301	33,332 (0%)	1,685	1,894 (+12%)	2,543	2,674 (+5%)
Southport West Sacramento, CA	3,000 acres	75,191	78,961 [74,138] ² (-1.4%)	6,484	5,919 [5,672] ² (-12.5%)	6,192	8,156 [7,480] ² (+21%)

Notes:

¹ Values in parentheses represent the percent increase in trips estimated by MXD versus the 2019 field measurements.

² Values in brackets represent the MXD external vehicle trips minus pass-by trips (see text below for explanation). The corresponding percentage (shown in parentheses) represents the percent change in trips estimated by MXD (after subtracting pass-by trips) versus the 2019 field measurements. du's = dwelling units. ksf = thousand square feet.

The following findings are derived from Table 6:

- For the three smaller sites, MXD produces a desirable result in which each validation site's external vehicle trips tend to be slightly overestimated. This is preferable to the converse in which MXD consistently underestimates actual trips. Accordingly, the results from MXD can be considered reasonably, but not overly, conservative.
- The goodness of fit at the Avalon validation site was a particularly important outcome, as the calibration sites were not in that part of the US and also not "manufactured mixed-use" in an otherwise suburban setting.
- Despite the calibration dataset consisting of a maximum site size of 221 acres and 1,840 units, the model's estimate was within 1.4% of the actual count for daily conditions. But AM and PM peak hour validation results did not fare as well. We suspect the AM peak hour underestimation could be associated with the various schools (i.e., three K-8 public schools and a public high school) in the community and their district boundaries (i.e., more students being transported from outside the community to these schools). The PM peak hour overestimation likely stems from reliance on ITE trip rates for single-family and multi-family uses, which turned out to be substantially higher

than was observed in one particular neighborhood⁴. The Southport validation site highlights how use of MXD may be considered for very large projects, but it would be prudent to perform spot checks of trip rates, understand school district boundaries, etc.

Table 7 displays the internal trip percentage reductions, and external trips made by transit and walk/bike for each validation site.

Table 7 – Percent Internal Trips and External Non-Auto Trips at Each Validation Site

Site	Percent Reduction in Daily Trips Due to			Percent Reduction in AM Peak Hour Trips Due to			Percent Reduction in PM Peak Hour Trips Due to		
	Internal Trips	External Trips		Internal Trips	External Trips		Internal Trips	External Trips	
		Transit	Bike/Walk		Transit	Bike/Walk		Transit	Bike/Walk
Safeway / Avalon Bellevue, WA	4.1%	6.4%	29.1%	9.2%	6.7%	35.0%	14.2%	6.5%	28.4%
Hazard Center, San Diego, CA	4.7%	4.9%	11.6%	10.1%	5.6%	14.3%	14.1%	5.3%	11.6%
Avalon Alpharetta, GA	5.4%	3.8%	2.3%	9.9%	4.1%	2.9%	12.0%	3.9%	2.3%
Southport, West Sacramento, CA	26.8%	1.8%	0.3%	39.0%	2.0%	0.3%	23.7%	2.2%	0.2%

Notes:
¹Output from MXD.

The following conclusions are drawn from the results in Table 7:

- It is not surprising that the Bellevue, WA site had a large bike/walk percentage given that is situated in Downtown Bellevue, where numerous jobs, retail, and recreation are situated close to the site.
- At the San Diego, CA site, internalization was greatest during the PM peak hour given the full activation of the various retail offerings and conclusion of the office workday.
- Despite the variety of complementary land uses at the Avalon Alpharetta, GA site, only modest levels of internalization were estimated. This is due to the amount of office space (over half a million square feet), which is disproportionately higher than the other uses. The site’s jobs-housing balance skews heavily toward non-residential. It should also be noted that about 4% of

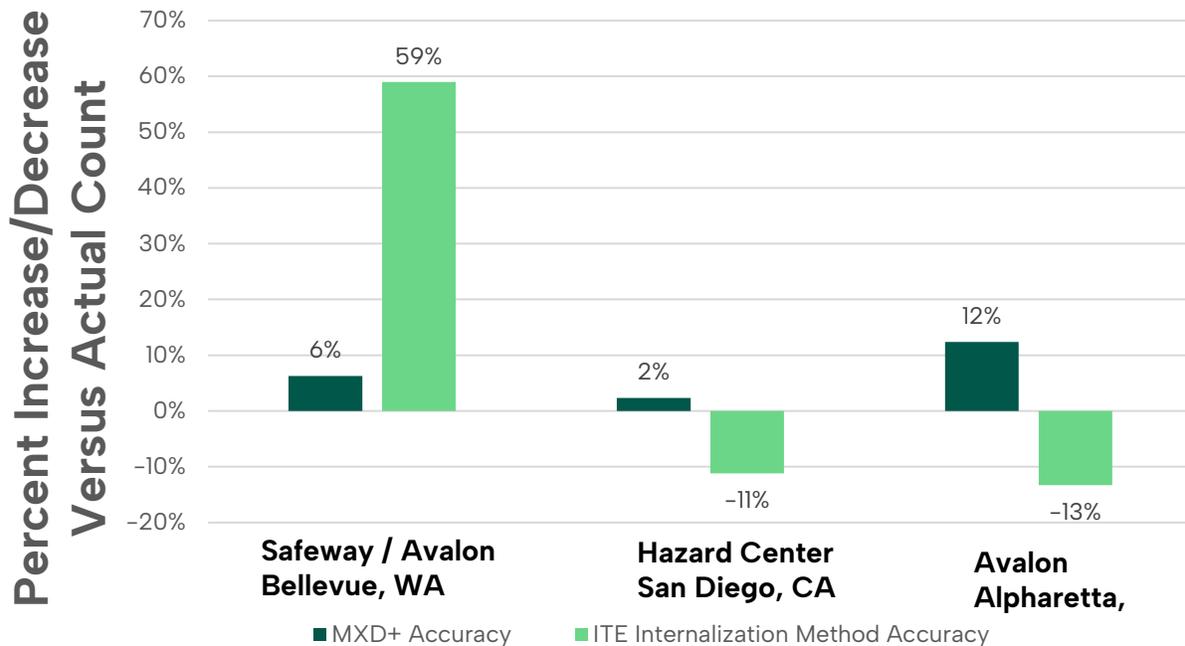
⁴ In one neighborhood consisting a combined 325 single-family and multi-family units, the measured vehicle trips entering/exiting the neighborhood during the PM peak hour trip was 51% below the unadjusted ITE trip rates for those uses. When translated to the 7,700 total units in Southport, this resulted in ITE gross trips beginning at a level much higher than was being generated.

external trips were assumed to be transit. This would equate to about 140 riders during the PM peak hour, which seems a bit excessive for the fixed-route bus service present.⁵

- At the Southport, CA site, internalization was greatest during the AM peak hour, which is expected given the effects of travel between home and school (to drop off students or work). External travel by transit and walk/bike was modest (less than 2.5%) as expected given that most households are not within walking distance of a bus stop and nearby destinations cannot easily be accessed on foot or by bike.

Charts 2 and 3 show results for AM and PM peak hours, respectively, of how MXD performed versus the ITE Internalization Method for the Bellevue, WA, San Diego, CA, and Alpharetta, GA validation sites. The Southport West Sacramento, CA site was excluded for the aforementioned reasons regarding the effects of pass-by traffic, which equally influence results from MXD and the ITE Internalization Method.

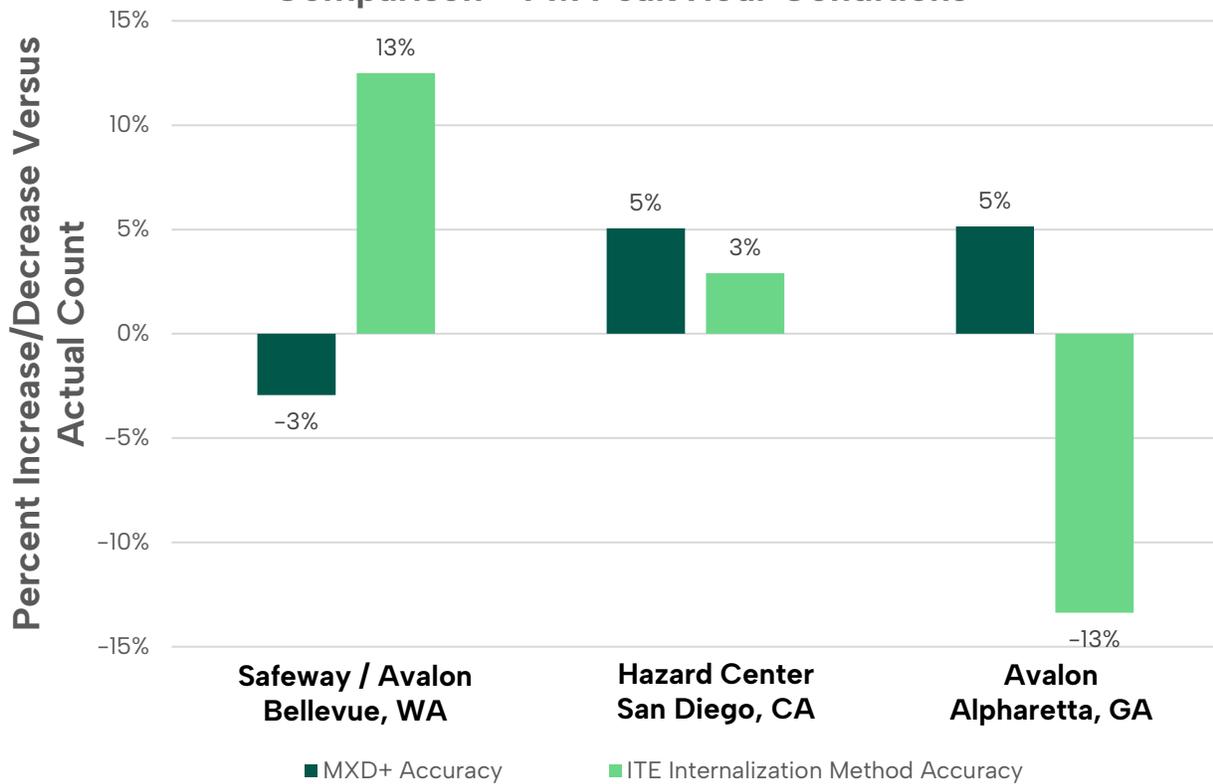
Chart 2: MXD Versus ITE Internalization Method Comparison – AM Peak Hour Conditions



As shown, the MXD estimate was closer to the actual count value at all three locations during the AM peak hour, and at two of the three locations during the PM peak hour. During the AM peak hour, the average absolute error was 7% for MXD and 28% for the ITE Internalization method. During the PM peak hour, the average absolute error was 4% for MXD and 10% for the ITE Internalization method. This clearly indicates that MXD estimates were more accurate than the ITE Internalization Method at the validation data sites.

⁵ In situations like this, local knowledge of expected transit ridership could dictate that the analyst modify MXD to assume no transit service, with an “off model” approach followed to determine whether any transit reductions are warranted. The presence of transit is a binary choice in MXD. The type of transit, headways, service duration, and geographic service area are not explicitly considered.

Chart 3: MXD Versus ITE Internalization Method Comparison – PM Peak Hour Conditions



Conclusions

This study has demonstrated that a minor recalibration of MXD has resulted in an analytical tool that accurately estimates the trip generation of mixed-use developments for weekday daily, AM peak hour, and PM peak hour conditions. By focusing the recalibration on 2019 conditions, the model was proven to develop accurate travel estimates despite the myriad changes in travel behavior that have occurred since the model was originally developed. The validation of the model against four mixed-use sites indicates that it may be applied across a wide range of geographies, project sizes, transportation mode availability, and land use mixes.

Paper Contributors

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References

Walters, Jerry, Bochner, Brian, and Ewing, Reid. 2013. *Getting Trip Generation Right: Eliminating the Bias Against Mixed-Use Development* (American Planning Association, 2013 PAS Memo).

Bochner, Brian, Hooper, Kevin, Sperry, Benjamin, and Dunphy, Robert, 2011. *NCHRP Report 684: Enhancing Internal Trip Capture Estimation for Mixed-Use Developments*. Washington, DC: National Cooperative Highway Research Program, Transportation Research Board.

Institute of Transportation Engineers, 2017 *Trip Generation Manual, 10th Edition*.

Institute of Transportation Engineers, 2017 *Trip Generation Handbook*.