

Improved Estimation Of Internal Trip Capture For Mixed-Use Developments

THIS ARTICLE DESCRIBES THE KEY TASKS AND FINDINGS OF NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM PROJECT 8-51, WHICH DEVELOPED IMPROVEMENTS TO THE EXISTING ITE METHODOLOGY FOR ESTIMATING INTERNAL CAPTURE. VALIDATION OF THE PROPOSED METHOD WAS BASED ON COMPARISON OF ESTIMATED EXTERNAL VEHICLE TRIP GENERATION WITH OBSERVED CORDON COUNTS.

INTRODUCTION

One of the key components of traffic impact analyses (TIA) for proposed land developments is the estimation of the number of trips that are expected to be generated by the site. For developments composed of a single land use, trip generation can be estimated using the Institute of Transportation Engineers' (ITE's) *Trip Generation*, 8th Edition or similar reference, based on certain characteristics of the proposed site.¹ For multi-use land developments, the process of estimating trip generation is slightly more complex due to the internalization of some trips between on-site land uses. ITE defines a "multi-use development" as a single real-estate project that consists of two or more ITE land-use classifications between which trips can be made without using the off-site road system.² Internal trip capture is used as a measure of the extent to which trips made at multi-use developments are internalized with both origin and destination within the development. Accurate estimation of internal trip capture for mixed-use developments benefits all parties involved with the development review process. In recent years, a new form of multi-use development, the mixed-use development (MXD), has emerged as a popular development style in both suburban greenfield and urban infill areas. MXD sites are developed in conformance with a single master plan, including fully integrated on-site land uses and deliberate layout and design of buildings and streets.

RESEARCH PROBLEM

Despite the importance of accurately estimating internal trip capture for MXDs, very little research exists on the subject. Prior to 2005, the most robust research effort examining internal trip capture was two studies from the early 1990s funded by the Florida (USA)

Department of Transportation (FDOT). These studies identified internal capture using intercept surveys of residents, employees, and visitors at six developments in south Florida. The FDOT studies would ultimately form the basis of the ITE-recommended procedure for estimating internal trip capture at multi-use developments, which is described in Chapter 7 of the *ITE Trip Generation Handbook*.³ For more details of the FDOT studies, the reader is referred to summaries located in Appendix C of the *Trip Generation Handbook*.⁴

While the ITE-recommended internal trip capture estimation procedure is the most frequently used method in practice, there are several limitations to the method. For example, the method includes data for only three land uses: residential, office, and retail. Although the data allow for estimation of internal capture during the p.m. peak hour, it does not allow data for the a.m. peak hour, so the current method does not support completion of traffic impact analyses for both street peak hours. Finally, there are no provisions in the method to account for certain features of the MXD that may have a profound impact on trip internalization, including the proximity of on-site land uses or the emphasis on pedestrian-oriented design.

Recognizing these limitations, the National Cooperative Highway Research Program (NCHRP) initiated Project 8-51 in 2005 to improve the methodology used to estimate internal trip capture within mixed-use developments.⁵ Among the project outputs were the following:

- A data collection framework and methodology to estimate internal trip capture at an existing MXD site; and
- A defensible improved methodology for estimating internal trip capture to determine appropriate reductions below single-use trip generation estimates.

The improved estimation method was developed using existing survey data from

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prior studies plus surveys of three additional MXDs conducted in the NCHRP project. The estimation method is based on the existing ITE procedure but expands it to cover both a.m. and p.m. peak periods, six primary land uses most frequently found at MXDs, and proximity of interacting land uses.

This article describes the key tasks and findings of NCHRP Project 8-51. For more details on the study methodology and analysis findings, readers are encouraged to read the project report, which is available from the Transportation Research Board.⁶

DATA COLLECTION METHODOLOGY

The first key task of the NCHRP 8-51 project was development of a methodology and procedural instructions for the data collection process as well as for selection of MXD sites that would be used for data collection. Preliminary steps of the data collection process included the following:

- Selection of representative MXDs that could be sufficiently isolated to collect data to determine both total external trip generation by mode and to determine internal trip making by interviewing the trip makers to determine trip origins, destinations, modes of travel, and related information; and
- Acquisition of owner/manager permissions to conduct the surveys and to obtain data describing each MXD and its land uses, including numbers of occupied development units.

Data were collected at the subject MXD sites during typical weekdays (Tuesday–Thursday) during the morning peak period (6:30 to 10:00 a.m.) and the weekday afternoon peak period (4:00 to 7:00 p.m.). Data obtained at each site included the following:

- **Origin-destination intercept** interviews of persons exiting land uses within the MXD; where not all doors could be covered due to limitations of resources, representative establishments were selected;
- **Door counts** of the number of people entering and exiting each MXD establishment at which interviews were conducted;
- **Cordon line counts, including** num-

Table 1. Characteristics of NCHRP 8-51 study MXD sites.

Characteristic ¹	Mockingbird Station	Atlantic Station	Legacy Town Center
Location	Dallas, Texas	Atlanta, Georgia	Plano, Texas
MXD Style	Urban Infill Transit-Oriented Development	Urban Infill	Suburban
Site Size (Acres)	7	120	75
Maximum Walk Distance (Feet)	700	1,600 ²	2,000
Residential (DU)	191	798	1,360
Retail (GLA)	156,100	434,500	196,300
Office (GSF)	114,600	550,600	310,800
Restaurant (GLA)	28,900	64,600	69,300
Hotel (Rooms)	<i>No On-Site Hotel</i>	101	404
Cinema (GLA/Screens)	31,500/8	87,000/16	27,100/5
Parking Spaces	1,528	7,300	6,070
Transit Service	Adjacent DART Light Rail Station	Heavy Rail via Shuttle; City Bus	Limited Suburban Bus/Hotel Shuttle

Source: Cited Reference 5

¹DU = dwelling units; GLA = gross leasable floor area; GSF = gross square feet of floor area.

²Reflects walking distance across main town center district.

bers of persons and vehicles by mode and direction; and

- Where specifics of a development required, additional interviews or counts to cover the characteristics of that development (for example, interviews of transit patrons accessing a rail station via an on-site access point).

Counts were used to factor interview data to represent the full population of travelers at the MXD site. Observed cordon counts were checked to ensure that total factored interview data compared logically with counts.

STUDY SITES

Three MXDs in the United States were selected for study in the NCHRP 8-51 project: Mockingbird Station in Dallas, Texas; Atlantic Station in Atlanta, Georgia; and Legacy Town Center in Plano, Texas. Each site contained at least five of the six land uses most frequently found in major MXDs: office, retail, restaurant, residential, cinema, and hotel. All were developed from a single master plan with fully integrated component land uses. Table 1 reports selected characteristics of the three MXD sites surveyed in NCHRP 8-51, including the quantities of each of the six land uses being examined for internal trip capture relationships.

Office properties at the study sites were generally mid-rise office towers, although some offices were vertically integrated above ground-level retail space or restaurants. Retail, restaurant, and cinema land uses were generally grouped in a “town center” configuration. Retail properties ranged from specialty stores to convenience/service shops. The retail component of the study sites included a large department store and grocery store at Atlantic Station and a large furniture store at Legacy Town Center. On-site restaurants ranged from high-turnover fast food to exclusive. Residential units at the study sites consisted of free-standing multi-family apartment buildings or owner-occupied townhomes. As with the offices, vertical integration between on-site residences and ground-level retail or restaurant was present at the study sites.

In general, the walkability of the study sites was excellent; maximum walking distances across the study sites were no more than one-half mile, although a majority of the walking activity occurred at much shorter distances. Parking (on-street and garage/surface lots) at the study sites was generally available to visitors but also included reserved parking spaces for on-site residents and employees. Observed vehicle occupancy rates were higher during

**Table 2. Proposed revision to ITE *Trip Generation Handbook*
Table 7.1 — unconstrained internal trip capture rates for trip
origins within a mixed-use development.**

Land-Use Pairs		Weekday Peak Hours	
		a.m.	p.m.
From OFFICE	To Office		
	To Retail	28%	20%
	To Restaurant	63%	4%
	To Cinema/Entertainment		0%
	To Residential	1%	2%
	To Hotel	0%	0%
From RETAIL	To Office	29%	2%
	To Retail		
	To Restaurant	13%	29%
	To Cinema/Entertainment		4%
	To Residential	14%	26%
	To Hotel	0%	5%
From RESTAURANT	To Office	31%	3%
	To Retail	14%	41%
	To Restaurant		
	To Cinema/Entertainment		8%
	To Residential	4%	18%
	To Hotel	3%	7%
From CINEMA/ENTERTAINMENT	To Office		2%
	To Retail		21%
	To Restaurant		31%
	To Cinema/Entertainment		
	To Residential		8%
	To Hotel		2%
From RESIDENTIAL	To Office	2%	4%
	To Retail	1%	42%
	To Restaurant	20%	21%
	To Cinema/Entertainment		0%
	To Residential		
	To Hotel	0%	3%
From HOTEL	To Office	75%	0%
	To Retail	14%	16%
	To Restaurant	9%	68%
	To Cinema/Entertainment		0%
	To Residential	0%	2%
	To Hotel		

Note: Blank cells indicate intra-land-use trips or locations not open in a.m. peak hours.
Italicized values indicate internal capture rates eligible for proximity adjustment.
Source: Cited Reference 5

- Legacy Town Center: infrequent suburban bus route adjacent to site plus private hotel shuttle to nearby business park; negligible transit mode share (less than 1 percent).

INTERNAL TRIP CAPTURE ANALYSIS

Using the factored interview data, researchers developed origin-destination (O-D) matrices that reported travel between each of the six land uses being examined as well as trips external to the site. Researchers excluded trips between the same land uses because ITE trip generation estimates already reflect trips within the same land use on the same site. From the O-D matrices, researchers computed internal trip capture percentages for origin and destination ends at land uses in the MXD. Researchers reviewed the internal trip capture rates for the three NCHRP study sites (and three FDOT sites where applicable) for logic related to nearby competing opportunities, proximity, connectivity, and specifics of the establishments to ensure the results were consistent with expectations. Researchers identified both consistencies and differences between the internal capture percentages for the same land-use pairs and directions. These consistencies and differences result from differences in proximity of the interacting land uses as well as the balance of development units. Other factors may also affect these percentages.

For each land-use pair and peak period, researchers identified up to six unique internal trip capture percentages, one for each of the three NCHRP sites plus up to three from the FDOT sites (where applicable). The highest percentages for each land-use pair examined represent the highest directional interaction shown by the survey data. The researchers considered these percentages to be unconstrained (or at least the least-constrained found): That is, they result from the most favorable balance of land-use development units as well as relatively close proximity. Tables 2 and 3 report the unconstrained internal trip capture percentages for trip origins and destinations within an MXD identified in this research. The data in Tables 2 and 3 are reported in a similar format as Tables 7.1 and 7.2 in the *Trip Generation Handbook*.⁷

the p.m., ranging between 1.07 and 1.12 in the a.m. and between 1.09 and 1.40 in the p.m. peak hour. Transit service at the study sites was as follows:

- Mockingbird Station: light-rail station adjacent to site; transit mode

share approximately 15 percent of external trips;

- Atlantic Station: frequent circulator shuttle connecting site and nearby heavy rail station; transit mode share approximately 5 percent; and

IMPROVED ESTIMATION METHODOLOGY

The second key task of the NCHRP 8-51 project was to develop an improved methodology for estimating internal trip capture for proposed MXD sites. Figure 1 shows a flowchart of the improved methodology, which is closely patterned after and builds upon the ITE-recommended methodology found in the *Trip Generation Handbook*.⁸ The ITE-recommended method applies internal trip capture percentages to estimated vehicle trips generated by each on-site land use (for which data are available) and distributes these trips among the other land uses at the site. In order to reflect the balance between quantities of each land use, directional trips between each land-use pair are constrained so the internal capture estimate includes only those trips for which there are enough of both origin and destination land uses to support trips. External travel is then computed by subtracting the estimated internal trips between on-site land uses from the single-site trip generation estimates. The NCHRP 8-51 project improves upon the ITE methodology by adding the following elements:

- Internal trip capture rates for the weekday a.m. peak hour;
- Internal trip capture rates for restaurant, cinema, and hotel land uses; and
- Adjustments to certain unconstrained internal trip capture rates (italicized values in Tables 2 and 3) to account for the effects of proximity (convenient walking distance) between interacting land uses to represent both compactness and design.

In addition to these improvements, researchers developed a convenient spreadsheet-based estimator tool to apply the methodology in practice. As shown in Figure 1, the improved method uses the following inputs:

- User-estimated a.m. and p.m. inbound and outbound vehicle trip generation for the six land uses as single-use, free-standing sites;
- Mode split for MXD trips to/from each land use—percent by auto, transit, and nonmotorized travel modes (walk/bicycle);
- Average vehicle occupancy to/from

Table 3. Proposed Revision to ITE *Trip Generation Handbook* Table 7.2—unconstrained internal trip capture rates for trip destinations within a mixed-use development.

Land-Use Pairs		Weekday Peak Hours	
		a.m.	p.m.
To OFFICE	From Office		
	From Retail	32%	8%
	From Restaurant	23%	2%
	From Cinema/Entertainment		1%
	From Residential	0%	4%
	From Hotel	0%	0%
To RETAIL	From Office	4%	31%
	From Retail		
	From Restaurant	50%	29%
	From Cinema/Entertainment		26%
	From Residential	2%	46%
	From Hotel	0%	17%
To RESTAURANT	From Office	14%	30%
	From Retail	8%	50%
	From Restaurant		
	From Cinema/Entertainment		32%
	From Residential	5%	16%
	From Hotel	4%	71%
To CINEMA/ENTERTAINMENT	From Office		6%
	From Retail		4%
	From Restaurant		3%
	From Cinema/Entertainment		
	From Residential		4%
	From Hotel		1%
To RESIDENTIAL	From Office	3%	57%
	From Retail	17%	10%
	From Restaurant	20%	14%
	From Cinema/Entertainment		0%
	From Residential		
	From Hotel	0%	12%
To HOTEL	From Office	3%	0%
	From Retail	4%	2%
	From Restaurant	6%	5%
	From Cinema/Entertainment		0%
	From Residential	0%	0%
	From Hotel		

Note: Blank cells indicate intra-land-use trips or locations not open in a.m. peak hours. Italicized values indicate internal capture rates eligible for proximity adjustment.
Source: Cited Reference 5

- each land use; and
- Average walking distance (feet) between land-use pairs.

From these inputs, the following outputs are produced:

- A.m. and p.m. peak hour internal person trips by land use in origin-destination form;
- A.m. and p.m. peak hour percent internal capture (person trips); and
- A.m. and p.m. peak hour inbound,

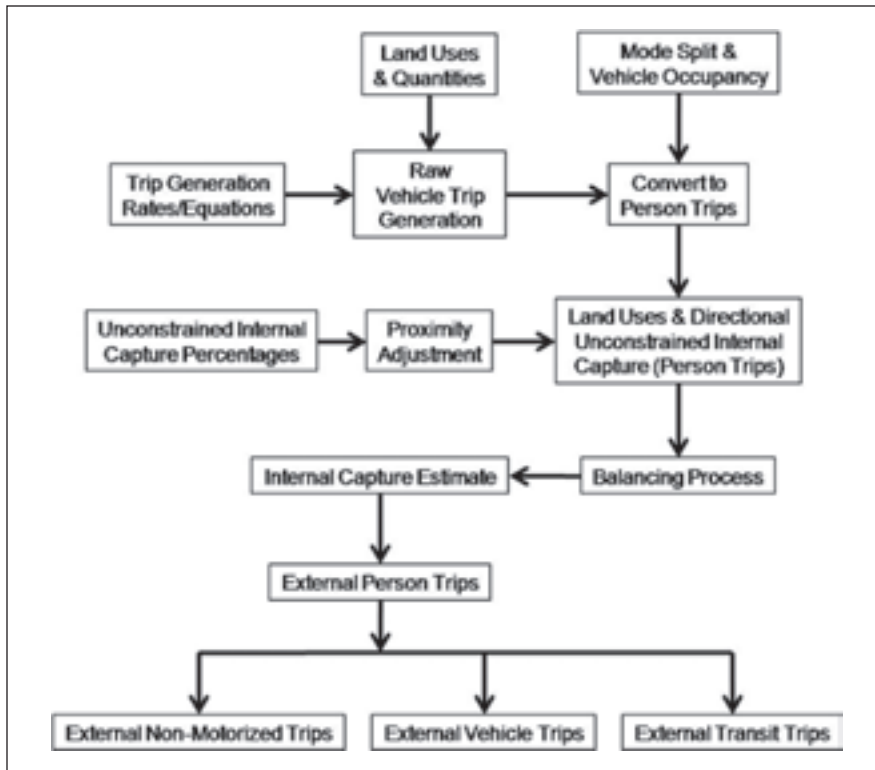


Figure 1. Generalized NCHRP 8-51 internal capture estimation method.

outbound, and total external person trips (trips to and from the development being analyzed) by mode (vehicles, transit, or nonmotorized).

VALIDATION

The validity of the improved method was tested by comparing the estimated trip generation from the method with observed cordon count data from MXDs. Cordon count data from the three NCHRP sites, the three FDOT sites, and one additional MXD site were used in the validation. For the seven MXD sites included in the validation, the proposed method was found to reduce estimation error by about half as compared to the existing ITE method and by three-fourths compared to raw ITE-based trip generation estimates.

RECOMMENDED MODIFICATIONS TO EXISTING ITE PROCEDURES

The recommended estimation method developed by NCHRP Project 8-51 does build on the current ITE internal trip capture procedures contained in the second edition of the *Trip Generation Handbook*. Incorporation of the NCHRP project's recommendations could be accomplished by doing the following:

- Expand Tables 7.1 and 7.2 of the *Trip Generation Handbook* to include all six land uses examined in the NCHRP project;
- Add a proximity adjustment to the unconstrained internal capture rates before estimating directional internal trips by land use and the balancing process; and
- Modify the data collection procedures to include those recommended in this project.

It should be noted that the findings of NCHRP Project 8-51 are being published for informational purposes; this research has yet not been advanced through ITE's process for development of recommended practices and therefore should not yet be considered an ITE-recommended methodology. This research will be considered for inclusion in an update to the ITE *Trip Generation Handbook*.

SUGGESTED FUTURE RESEARCH

The NCHRP 8-51 project made progress to improve estimation of internal capture for MXDs. However, the database is still sparse, and much that is thought to be logical about MXD travel characteristics is still

unproven and largely untested. The results presented in this paper are based on surveys of six mixed-use developments, and validation was limited to seven such developments. Caution should be exercised in application of this methodology. For example, it cannot be concluded that the methodology will be appropriate for mixed-use developments that differ substantially from those surveyed.

Two of the research efforts recommended by the research team are as follows:

- Collect more data at MXDs; the researchers think data are needed from at least six more sites that have five to six land uses; and
- Independent of the additional data collection, test the applicability of the proposed methodology using data from MXDs of different sizes, character, and land-use components; use validation tests similar to those used in NCHRP 8-51. To do so, the only data needed are a complete directional cordon count for morning and afternoon peak hours plus development data and a good site plan from which to estimate proximities.

Practitioners, researchers, and other interested parties are encouraged to collect and contribute additional data using the data collection procedures described in research report. Those data could be used to further enhance the accuracy of the proposed methodology and/or expand the number of land-use classifications covered by the methodology. New data should be forwarded to the Institute of Transportation Engineers. ■

References

1. *Trip Generation*, 8th Edition, Institute of Transportation Engineers, Washington, DC, December 2008.
2. *Trip Generation Handbook*, 2nd Edition, Institute of Transportation Engineers, Washington, DC, June 2004.
3. Ibid.
4. Ibid.
5. Bochner, Brian, Kevin Hooper, and Benjamin Sperry, *Improved Estimation Method for Estimating Internal Capture for Mixed-Use Developments*, draft final report, NCHRP Project 8-51, Texas Transportation Institute, November 2009.
6. Ibid.
7. ITE, 2004.
8. Ibid.



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