Estimation of Pass-By Trips Using a License Plate Survey

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A significant portion of the travel attracted by generators such as shopping centers and several other convenience-oriented land uses are pass-by trips. Methods exist for handling pass-by trips in traffic impact analysis. However, there is a dearth of data regarding the percentage of pass-by trips for a particular type and intensity of land use. The traditional way of determining the number of pass-by trips is to conduct a face-to-face interview survey. This is, however, a time-consuming and intrusive process. A study was conducted to determine whether it is possible to estimate the percentage of pass-by trips by using a license plate survey instead of the traditional interview survey. Two separate data collection efforts were conducted. At each location the license plate observations were matched by using a standard computer program. In both cases the percentage of pass-by trips obtained by a license plate survey was found to be very close to the results obtained by an interview survey. However, further studies must be conducted before the methodology can be accepted as a standard procedure for estimating pass-by trips. At a minimum, the procedure can place upper and lower bounds on the percentage of pass-by trips for a particular existing development. This nonintrusive method will be especially helpful (in terms of management of time and personnel) in determining the percentage of pass-by trips for large developments when a face-to-face interview would involve an extensive effort.

INTRODUCTION

Shopping centers and several other convenience-oriented land use types such as banks, gasoline stations, and fast-food restaurants have slightly different trip generation characteristics from other land use types. A significant portion of the trips attracted by these generators are "captured" from the adjacent traffic stream. Trips to such developments may be broken down into three categories (*1*): primary, diverted, and pass-by.

A primary trip destined to a retail facility is one in which the purpose of the trip is shopping at the site and the pattern of the trip is home-shopping-home.

A diverted linked trip to a retail facility is one in which the shopping destination is a secondary part of the primary trip and the pattern of the trip is, for example, work-shopping-home. A diverted linked trip as shown in Figure 1 involves a route diversion to reach the site (*2,3*).

A pass-by trip comes directly from the traffic stream passing the facility on the adjacent roadway system and does not require diversion from another roadway.

Estimating the percentage of pass-by trips is very important for many engineering studies, including traffic impact analysis. The percentage of pass-by trips varies with the size of the development, its geographical location, the nature of the roadway system, and certain other variables. Methods exist for handling pass-by trips in traffic impact analysis (*3*). However, there is a dearth of data regarding the percentage of pass-by trips for particular types and intensities of land use.

The traditional means of determining the percentage of pass-by trips is to conduct a face-to-face interview survey. Because this is a time-consuming and labor-intensive process, most of the traffic impact studies conducted across the nation either do not consider pass-by trips in their analysis or use the scatter plots and regression equations provided by ITE in its report *Trip Generation* (*2*). In fact, responses to the survey questionnaire (*5,6*) revealed that 63 percent of the states depend entirely on the ITE data to determine the percentage of pass-by trips. Twenty-six percent of the states try to use local pass-by percentages. In the absence of such data, they use the ITE rates. Eleven percent do not incorporate pass-by trips in their analyses. Therefore, 89 percent of the states depend either directly or indirectly on the ITE data base. Unfortunately, however, the size of the data base is quite small, and the regression equations, when available, have very low R^2 values (of the order of 0.3). Hence, the validity of the curves is not beyond question. Moreover, using these curves blindly would fail to take into account the site-specific characteristics of the development under consideration.

In the 1991 edition of the ITE report (*2*) a new methodology for estimating the percentage of pass-by and diverted linked trips was suggested based on the volume of the traffic available to produce pass-by and diverted linked trips (shown in Figure 2) multiplied by an attraction factor related to the size of the development. The following set of equations is suggested (*2*):

$$N_{pb} = p \times VOL_{pb}$$
$$N_d = p \times VOL_d$$
$$p = a_o + a_1 G$$

where

p = probability that a driver already in the traffic stream will stop at the generator ($0 \leq p \leq 1$),
VOL_{pb} = passing traffic stream volume available to produce pass-by trips,
VOL_d = traffic volumes on other streets available to produce diverted linked trips,
G = gross leasable area of development ($\times 1000$ m^2), and
a_0, a_1 = coefficients to be calibrated.

More recently, Moussavi and Gorman (*7*) have proposed a method for estimating pass-by trips by using multiple regression. The independent variables used in their regression analysis include floor area, volume-to-capacity (v/c) ratio, average daily traffic (ADT), and percentage of residential and commercial land use within a meter's radius of the site. These methods are also data

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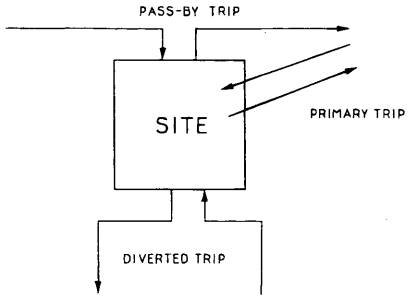

FIGURE 1 Schematic diagram showing primary, pass-by, and diverted linked trips (*3*).

intensive and need further evaluation. Therefore, the need for a quick and easy method to estimate pass-by trips was felt.

STUDY OBJECTIVE

The objective of the study was to determine whether it is possible to estimate the percentage of pass-by trips by using a license plate survey instead of the traditional interview survey. Two separate data collection efforts were conducted:

- At Eastway Plaza, a shopping center in Lafayette, Indiana; and
- At a Marsh supermarket in Castlecreek Plaza, Indianapolis, Indiana.

In both cases the percentage of pass-by trips obtained by license plate survey was compared with the results obtained by a face-to-face interview survey.

DATA COLLECTION

At Eastway Plaza the data collection was done in two parts:

1. A group of 13 interviewers intercepted people entering and leaving the stores and conducted a face-to-face interview survey.
2. One person was assigned to each of the following locations (see Figure 3): Driveway 1, access to US 52; driveway 2, access to Greenbush Street (closest to US 52), and driveway 3, secondary access to Greenbush Street.

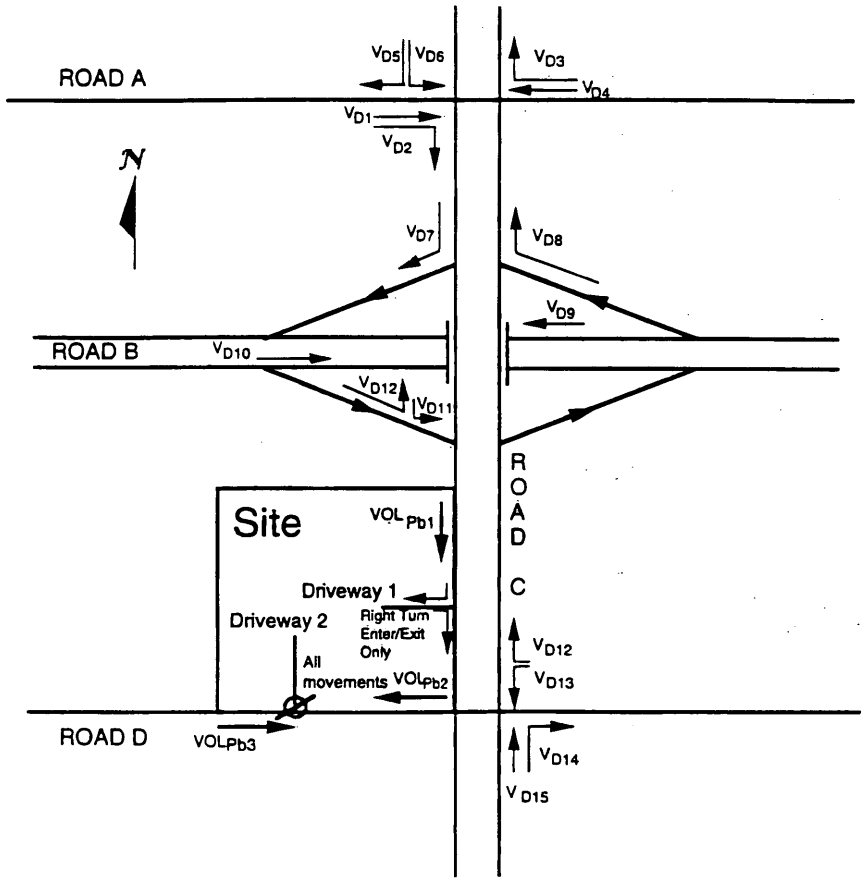

FIGURE 2 Identification of pass-by and diverted linked trip volumes (*2*).

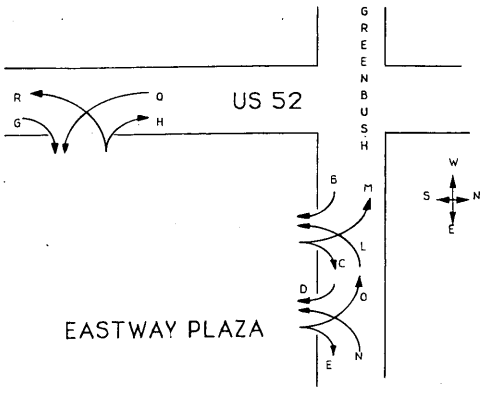

FIGURE 3 Turning movements at Eastway Plaza.

At each of these locations the last three digits of the license plates of vehicles entering and leaving the shopping center were recorded, along with the time of observation and movement of the vehicles after leaving or before entering the shopping center parking lot.

At Eastway Plaza, data were collected for 1 hr (5:00 to 6:00 p.m.) during the adjacent street evening peak period on a typical weekday.

An Indianapolis transportation engineering firm had conducted an interview survey of the customers leaving the Marsh supermarket at Castlecreek Plaza. Therefore, at this site only a license plate survey of the vehicles entering and leaving the plaza by the two driveways and of customers leaving the Marsh store was conducted. Two persons collected the license plate numbers of customers leaving the Marsh store and three persons recorded the final four license plate characters of the vehicles entering and leaving the shopping center driveways.

At Castlecreek Plaza, data were collected on a Friday for 1.5 hr, between 5:00 and 6:30 p.m.

DATA ANALYSIS

In both cases the results of the interview survey were analyzed, and the data from the license plate survey were stored in an input file.

The summary of interview survey results at Eastway Plaza is shown in Table 1. The vehicle movements at Eastway Plaza were defined as shown in Figure 3.

All possible combinations of in/out movements were identified and the license plate observations were matched using a computer program. The program identified the number of cars using each possible in/out combination. From the turning movements at the driveways and the researchers' ideas about the local travel patterns and adjacent land uses, the trips were classified as primary (PR), diverted (DI), or pass-by (PB). In many cases, however, no clear decision could be taken regarding the trip type. The results of the matches and the three predicted trip types are shown in Table 2. PB/DI and PR/DI in Table 2 denote the trips for which no decision could be made as to whether they were pass-by or diverted and primary or diverted, respectively.

The total number of matches obtained was 135. From the results of the matches, the following sets of equations were generated (see Table 3):

$$T_{PR} + T_{PB} + T_{DI} = 135 \quad (1)$$

$$T_{PB1} = 19 \quad (2)$$

$$T_{DI1} = 25 \quad (3)$$

$$T_{PB2} + T_{DI2} = 41 \quad (4)$$

$$T_{PR} + T_{DI3} = 50 \quad (5)$$

TABLE 1 Summary of Interview Survey at Eastway Plaza

STORE NAME	TOTAL # OF TRIPS	PASS-BY TRIPS	NON-PASS-BY TRIPS	NOT KNOWN
B.J.'s	5	0	5	0
Carruso's	15	2	13	0
MVP Sports	6	2	4	0
Aunt Orva's	4	1	1	2
Frame Shoppe	1	0	1	0
Queen City	5	0	3	2
Videoland	59	11	42	6
Fast Food	13	6	7	0
Radio Shack	13	5	5	3
Nutri System	10	1	5	4
Bar Barry	36	13	17	6
Progolf	4	2	2	0
Tropicana	2	0	2	0
Homework	4	0	1	3
TOTAL	177	43	108	26
(PERCENTAGE)		(28.5%)	(71.5%)	

TABLE 2 Results of License Plate Matches at Eastway Plaza

MOVEMENT TYPE	# OF MATCHES	TRIP TYPE	MOVEMENT TYPE	# OF MATCHES	TRIP TYPE
G→H	17	PB/DI	B→C	9	PB/DI
Q→R	3	PB/DI	B→E	10	PB/DI
N→O	0	PB/DI	N→M	1	PB/DI
L→M	1	PB/DI	L→O	1	PB/DI
D→E	1	PB/DI	D→C	0	PB/DI
G→R	17	PR/DI	Q→H	3	PR/DI
B→M	4	PR/DI	B→O	7	PR/DI
L→C	5	PR/DI	L→E	6	PR/DI
D→O	0	PR/DI	D→M	0	PR/DI
N→E	0	PR/DI	N→C	0	PR/DI
G→E	5	PB	G→O	1	DI
G→C	10	PB	G→M	12	PB/DI
Q→E	2	PB/DI	Q→O	0	PR/DI
Q→C	5	PB/DI	Q→M	2	PR/DI
N→R	0	PB/DI	N→H	0	PB/DI
D→R	0	DI	D→H	0	PR/DI
B→R	5	PB/DI	B→H	6	PR/DI
L→R	1	PB	L→H	1	PB/DI

TABLE 3 Summary of Table 2

Trip Type	Total Matches
PB	19
DI	25
PB/DI	41
PR/DI	50
Total	135

where

$$T_{PB} = T_{PB1} + T_{PB2} \quad (6)$$

$$T_{DI} = T_{DI1} + T_{DI2} + T_{DI3} \quad (7)$$

In Equations 1–7

T_{PR}, T_{PB}, T_{DI} = number of primary, pass-by, and diverted trips, respectively,
T_{PB1} = number of trips that are clearly pass-by,
T_{DI1} = number of trips that are clearly diverted,
T_{PB2}, T_{DI2} = number of pass-by and diverted trips in the PB/DI trip category, and
T_{PR}, T_{DI3} = number of primary and diverted trips in the PR/DI trip category.

T_{PB} has two components, T_{PB1} and T_{PB2}; and T_{DI} has three components, T_{DI1}, T_{DI2}, and T_{DI3}.

This set of equations reduces to

$$T_{PB2} + T_{DI2} = 41$$
$$T_{PR} + T_{DI3} = 50$$

This is a set of two equations and four unknowns that has no unique solution.

To circumvent this problem, the trip types were reduced from the three mentioned before (pass-by, diverted, and primary) to two, pass-by (PB) and non-pass-by (NPB). This was done by lumping the diverted (DI) and primary (PR) trips together into a common category, non-pass-by (NPB) trips. The equations reduced to

$$T_{PB2} + T_{NPB2} = 41$$

This is one equation and two unknowns, which also has no unique solution.

Two other ways to circumvent the problem faced are as follows:

1. Decide on the trip types based on the turning movements at the adjacent intersections. This method could yield a unique solution, but in some cases the trip type may still be debatable and subjective. For example, in the case of Eastway Plaza, if a license plate survey had been conducted at the intersections of US 52/Greenbush and the next intersection toward the south simultaneously with the surveys at the driveways, it would probably have been possible to decide on the trip types in most of the cases. Because of time constraints this method was not pursued further.
2. Split up the two trip types, pass-by and non-pass-by, and conduct an "extreme analysis." This solution would provide a range of the percentage of pass-by trips for the proposed development. From the range, a plausible percentage of pass-by trips may be estimated. The analysis was based on this approach.

The results of the matches (based on two trip types, pass-by and non-pass-by) at Eastway Plaza are shown in Table 4.

The results of the interview survey conducted by the consultants are shown in Table 5. The turning movements at Castlecreek Plaza were designated as shown in Figure 4. The results of the license plate matches at Castlecreek Plaza are shown in Table 6.

TABLE 4 Results of License Plate Matches at Eastway Plaza Based on Two Trip Types

MOVEMENT TYPE	# OF MATCHES	TRIP TYPE	MOVEMENT TYPE	# OF MATCHES	TRIP TYPE
G→H	17	PB/NPB	B→C	9	PB/NPB
Q→R	3	PB/NPB	B→E	10	PB/NPB
N→O	0	PB/NPB	N→M	1	PB/NPB
L→M	1	PB/NPB	L→O	1	PB/NPB
D→E	1	PB/NPB	D→C	0	PB/NPB
G→R	17	NPB	Q→H	3	NPB
B→M	4	NPB	B→O	7	NPB
L→C	5	NPB	L→E	6	NPB
D→O	0	NPB	D→M	0	NPB
N→E	0	NPB	N→C	0	NPB
G→E	5	PB	G→O	1	NPB
G→C	10	PB	G→M	12	PB/NPB
Q→E	2	PB/NPB	Q→O	0	NPB
Q→C	5	PB/NPB	Q→M	2	NPB
N→R	0	PB/NPB	N→H	0	NPB
D→R	0	NPB	D→H	0	NPB
B→R	5	PB/NPB	B→H	6	NPB
L→R	1	PB	L→H	1	PB/NPB

TABLE 5 Results of Interview Survey at Marsh Supermarket (Conducted by A&F Engineering, Inc.)

TIME	PASS-BY TRIPS	NON-PASS-BY TRIPS
5:00-5:15	4	2
5:15-5:30	5	5
5:30-5:45	6	9
5:45-6:00	6	4
6:00-6:15	5	7
6:15-6:30	6	9
TOTAL	32	36
(PERCENTAGE)	(47%)	(53%)

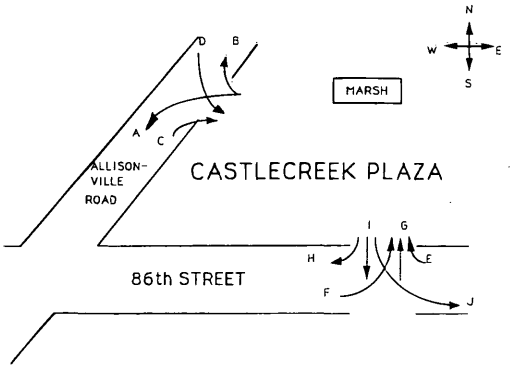

FIGURE 4 Turning movements at Castlecreek Plaza.

As with the case of Eastway Plaza, the researchers used the turning movements at the driveways along with their knowledge about nearby land uses and travel patterns in the vicinity of the site to classify each pair of in/out movements as pass-by, non-pass-by, or both.

For example, movement F most likely came from I-465 approximately 0.5 mi south of 86th Street. If there were easy access for a return to I-465 to the east and south via J, the analysts would have considered FJ either a pass-by or diverted trip, and therefore "PB/NPB" in Table 6. But because trips returning to I-465 usually use Allisonville Road, movement FH is considered a diverted or primary trip (NPB in Table 6), and FJ is listed as pass-by only.

Using knowledge of the surrounding street network and land uses is better than adopting a rigid rule such as "all left-in–left-outs are pass-by trips." For example, movement QR in Figure 2 could be a trip diverted from other north-south routes east or west of US 52.

TABLE 6 Results of License Plate Survey at Marsh Supermarket, Castlecreek Plaza

MOVEMENT TYPE	# OF MATCHES	TRIP TYPE	MOVEMENT TYPE	# OF MATCHES	TRIP TYPE
C→A	0	NPB	E→I	6	PB/NPB
C→B	29	PB/NPB	E→J	0	NPB
C→H	2	NPB	F→A	0	NPB
C→I	1	NPB	F→B	6	PB
C→J	2	PB	F→H	3	NPB
D→A	3	PB	F→I	4	PB/NPB
D→B	22	NPB	F→J	3	PB
D→H	3	PB/NPB	G→A	0	PB/NPB
D→I	5	PB/NPB	G→B	11	PB/NPB
D→J	4	PB	G→H	7	PB/NPB
E→A	0	PB/NPB	G→I	1	PB/NPB
E→B	15	PB/NPB	G→J	1	PB/NPB
E→H	6	PB			

RESULTS

The total number of matches and the number of PB, NPB, and PB/NPB trips for the two study sites are shown in Table 7. PB/NPB trips denote the trips for which no decision could be taken (based on their turning movements) as to whether they were pass-by or non-pass-by.

PB_{max} and PB_{min} were calculated under the assumption that all the PB/NPB trips were pass-by and non-pass-by, respectively. PB_{avg} was calculated as $(PB_{max} + PB_{min})/2$. Therefore, PB_{avg} is the number of pass-by trips when there is an equal likelihood that the PB/NPB trips are pass-by or non-pass-by. The percentage of PB_{avg} trips was found to be very close to the percentage of pass-by trips obtained from the interview survey.

The results can also be explained by the following heuristic argument. The actual number of pass-by trips is a random variable and has to lie between PB_{max} and PB_{min} ($PB_{min} \leq PB_{actual} \leq PB_{max}$). It was assumed during the analysis that the NPB trips have two components, diverted (DI) and primary (PR). The PB/NPB trips therefore have two components, PB/DI and PB/PR. In this case, however, there is no occurrence of PB/PR trips, and hence it is a null set. In the absence of any prior information, the probability of the PB/NPB trips' being pass-by or non-pass-by was set as equal (noninformative prior). Under the assumption that the distribution of PB/NPB trips is symmetric, PB_{avg} gives the minimum variance unbiased estimate of the actual number of pass-by trips.

CONCLUSIONS

The percentage of pass-by trips obtained by a license plate survey in both cases was found to be very close to the results obtained by an interview survey. However, further studies have to be conducted before the methodology can be accepted as a standard procedure for estimating pass-by trips. At a minimum, the procedure can place upper and lower bounds on the percentage of pass-by trips for a particular existing development. The range will be small if the analyst has a thorough knowledge about the travel patterns in the area, if most of the driveway turning movements are unambiguous, or both. The range will also be small if the license plate survey includes the adjacent intersections in addition to the driveways.

This method will be especially helpful (in terms of time and personnel requirements) in determining the percentage of pass-by trips for large developments for which a face-to-face interview would be an intensive effort. Even at rather small sites such as Eastway Plaza and Castlecreek Plaza, providing and positioning personnel to conduct interviews can be challenging. Some businesses have so many customers that two or more interviewers are required to administer even a short face-to-face survey. At less active businesses in a shopping center one person could try to cover several adjacent businesses if the spatial distribution of the stores (distance) allowed the interviewer to move quickly to interview arriving customers at the various business entrances.

At Eastway Plaza 13 interviewers and only 3 license plate recorders were employed. The positioning of the interviewers is difficult to plan and may have to be revised during the course of the data collection. Recording of license plates is much easier to plan and, in extreme cases, can even be automated by the use of audio or videotape recorders.

As the size of the shopping center increases, the disparity between the number of personnel needed to conduct an interview survey and the number required to record license plates at driveways increases. And, of course, it is the larger shopping centers that have the greatest need to be studied.

TABLE 7 Summary of Results

SITE	TOTAL MATCHES	PB	NPB	PB/NPB	PB_{max}	PB_{min}	PB_{avg}	INTER-VIEW
EASTWAY	135	19	75	41	60	19	39.5	
(%)		14	56	30	44	14	29	28.5
MARSH	134	24	28	82	106	24	65	
(%)		18	21	61	79	18	49	47

Another important advantage of a workable license plate survey as a substitute for face-to-face interview survey is that it does not interfere with customers en route to or from the businesses or site being studied. This nonintrusive technique is certainly preferred by the customers and the interviewers. It may also be preferable to the property owner when permission to conduct an on-site survey is requested. In extreme cases when a property owner's consent cannot be obtained the license plate study could be conducted from adjacent or nearby property or public right-of-way.

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