Improved Sampling Techniques To Determine Trip Characteristics for Traffic Impact Analyses

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The development of sampling and surveying methodologies for statistically reliable trip characteristic surveys of land developments was researched. The two goals of the sampling methodology research were to (a) determine the effect of a monetary incentive on questionnaire response rates and (b) estimate the coefficients of variation of primary and diverted trip types and hence suggest a statistically based sample size guideline for a particular type of land development—a community-scale shopping center. The final part of the survey methodology research was to examine bias potential in land development surveys. On the basis of the finding that current sampling and surveying methods were inadequate to determine statistically reliable trip characteristics for some land developments, a hybrid prototype survey technique was designed and tested. Reduction and analysis of the test survey data revealed important findings. First, the monetary inducement of $1.00 increased the survey questionnaire response rate nearly threefold, from 11 percent to nearly 30 percent. Thus, sampling error at a given confidence level can be reduced. Second, the coefficients of variation of trip lengths varied substantially on an hourly basis, with the total day averages estimated at 0.8 and 1.6 for primary and diverted trip types, respectively. With minor verification these can be used as transferrable parameters for conducting statistically reliable surveys at other locations. And third, a test was conducted for potential intrasite sampling location bias. The test was designed to detect bias potential without affecting the data; the potential for bias was detected. The research underscores the need for establishing appropriate sampling techniques as developed in this research.

Frequently, trip characteristics are estimated or inferred from survey data that are biased because of an inappropriate surveying methodology. More often, the data were not collected using statistically reliable sampling methods. Often the traffic analyst is removed from the data collection method (*1*) and thus the subsequent traffic impact analysis, mitigation determination, and corresponding regulatory exactions are inaccurate. Transferable and statistically sound sampling and surveying methodologies are needed so that reasonably accurate traffic impact assessment, mitigation, and exactions can occur.

Three major groups of trip characteristic parameters are used in impact modeling and regulatory exactions of land development: trip generation rates, trip types, and trip lengths. Trip generation rates are well studied for the majority of land development types, and data coverage is throughout the day (*2*). Although trip type research is not complete, it is increasing substantially. However, little transferable research or guidance exists in the area of trip length determination, and this parameter will be increasingly significant in both traffic impact fee assessments and concurrency evaluations (*3*).

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In most site traffic impact analysis references, the trip length parameter is not addressed in detail. Although there were some earlier studies of land use specific trip lengths (*4,5*), compared with the trip type parameter, little research has been done on this important parameter. Commonly, trip length is considered during the trip distribution and consequently the assignment steps of the modeling sequence. One recent and comprehensive publication, *Traffic Access and Impact Studies for Site Development: A Recommended Practice*, identifies three commonly used methods of trip distribution: analogy, gravity model, and surrogate data (*6*). In the last two methods, the trip length frequency distribution (or average) is a major parameter and requires careful selection on the basis of accurate sampling and surveying of land development.

CURRENT METHODS OF TRIP CHARACTERISTICS SURVEYS

The three common survey methods used to ascertain trip-making characteristics of land development are roadside interview surveys, patronage (sidewalk) interviews, and driver postcard surveys. Each was examined to determine its applicability to the task of data collection for determining trip characteristics of land development. The factors of applicability considered were accuracy, response rate, and survey bias potential.

Roadside interview surveys typically are employed along public roadways (*7*) and are commonly used at driveways of land developments. For land development types with limited access, the roadside interview survey may provide reasonable accuracy and a standard response, and the bias potential would be similar to that of the patronage (sidewalk) interview. However, complete and proportioned sampling of all driveways would have to be implemented to prevent intrasite sampling location bias.

The most common method of obtaining data (at shopping centers) is the patronage (sidewalk) interview (*8,9*). The drawback of this method is its potential for interview location-induced bias. This bias could be severe at neighborhood and community-scaled retail centers with multiple tenants and large variations in pedestrian traffic, unless extensive interview locations and rate planning (to ensure random sampling) are employed.

The third survey type is the driver postcard method. Although response rates are poor—a recent source (*10*) reports response rates in the range of 5 to 15 percent—some advantages of this type of "self-administered" survey are that (a) more candid results are possible because the response is done in private and generally at an unhurried pace, (b) the response is elicited without the pressures of a personal interview, and (c) it is generally the least expensive survey method (*11*).

TEST SURVEY SITE SELECTION

The trip characteristics of retail shopping centers were chosen for the research for two reasons. First, shopping center trip characteristics are perhaps the most complex of all prevalent single land development types. Second, the sample and survey design methodology for shopping centers must consider a host of factors (e.g., multiple driveways; multiple tenants/or pedestrian access points, or both; and hourly variation) not often present together in other land development types. An existing shopping center in Brooksville, Florida, was selected for low to moderate area growth, the tenant stability of the survey site, a tenant mix typical of community-scaled shopping centers, and multiple driveway and access points. The shopping center serves a primary trade area of approximately 26,400 persons. It encompasses 17 acres of land, consists of 162,000 ft^2 of gross retail space, and has as major tenants a discount department store and a grocery store.

PLANNING, DESIGN, AND EXECUTION

Sample Size

The total sample size equation used in this research was based on one that is frequently used in regional household surveys. The form is

$$N = CV^2 \times Z^2/E^2 \qquad (1)$$

where

N = number of required samples,
CV = coefficient of variation,
Z = normal variate, and
E = accuracy level expressed as a proportion.

A target confidence level of 95 percent ($Z = 1.96$) and a 10 percent acceptable error were selected. For the coefficient of variation, the value selected initially was unity ($CV = 1.0$), based largely on the research and recommendation by Smith (*12*). The required (unstratified, unclassified) sample size based on Equation 1 is $N = 384$.

Questionnaire Distribution Method

After considering the available survey methods, it was determined that a hybrid interview-postcard survey method would need to be developed to provide relatively unbiased sampling. This method would allow testing for bias potentials, particularly intrasite sampling location bias. It would in addition provide the vehicle for testing a response incentive. It was hypothesized that by offering a monetary ($1.00) incentive to the potential respondents, the response rate would be increased substantially. Accordingly, the following are the specific aspects of the final hybrid sampling design:

1. Questionnaires are distributed randomly throughout the parking lot of the shopping center.
2. Questionnaires are not given to individuals; rather they are left on the parked vehicle.
3. A monetary inducement to complete the questionnaire is stated in the instructions.
4. As respondents exit the parking lot, they return the completed questionnaire to a survey team member and receive $1.00. Recorded on the returned survey are the time and driveway location number at which the questionnaire was received.

Questionnaire Format

The primary data sought from the respondents were the origin of their (incoming) trip and their destination after leaving the center. By obtaining the origin-destination (O-D) information, the type of trip and the trip length could be determined through geocoding. In addition to allowing identification of the exact location (i.e., street address) of the respondent's origin or destination, a response area for "nearest intersection" was provided. In effect, the modified questionnaire accommodated both a "preferred" and an "unpreferred" procedure of determining trip O-D information, thereby minimizing a portion of procedural bias. Because of the need to test specific bias theories (and hence minimize nonresponse bias), the response form was kept brief.

Temporal Sampling Considerations

On the basis of information in a report to a technical committee of the Florida ITE Section (FSITE) (A. S. Byrne, unpublished data, 1975), Wednesday was the day selected for both the test and control surveys because it represented the smallest daily variation in the traffic of a community-scaled shopping center. Likewise, the questionnaire distribution rate throughout the day was based on hourly traffic variation information within the FSITE report, and continual adjustment of the distribution rate was made so that temporal bias was minimized.

REDUCTION AND ANALYSIS

The usable responses (82 percent) were geocoded and classified into the three trip types—primary, diverted, and captured—pursuant to work by Oliver (*13*). The data attributes of each response were then input into a spreadsheet program and further reduction and evaluation were performed. The survey summary totals were 31, 41, and 28 percent for primary, diverted, and captured trips, respectively. The average trip lengths were 4.7 and 1.0 mi (7.6 and 0.6 km) for primary and diverted trips, respectively. The weighted average trip length was 1.9 mi (3.2 km).

Trip Type Composition and Implications

One important trend evident from the test survey data is the difference between the percentage of trip types in the p.m. peak hour versus that of the entire day. The data revealed a p.m. peak hour (4:30 p.m. to 5:30 p.m., adjacent street traffic) profile of 22, 44, and 34 percent for primary, diverted, and captured, respectively. These percentages are significantly different (in chi-square tests with confidence levels of both 90 and 95 percent) from the totals for the entire day. These differences can result in considerable error and controversy, particularly if the p.m. peak trip type percentages (and trip lengths) are used for traffic modeling, mitigation exactions, and impact fee calculations, as is frequently the practice.

Trip Length

The lengths of both primary and diverted trips varied substantially throughout the day. Primary trip lengths tended to be greater than the daily average during the early morning, midafternoon, and early evening hours. They tended to be less than the average during the periods of high adjacent street traffic volumes. Diverted trip length correlated directly with the development's relative traffic volume. It tended to be greater than the day's average of 1.0 mi (0.6 km) during the noon and afternoon rush hours and considerably lower during the early and midafternoon.

A more important result of the data reduction is seen in the hourly variation and total day average coefficient of variation (trip length). Although the average coefficient of variation (CV) for the primary and diverted trips is 0.8 and 1.6, respectively, both CVs vary substantially throughout the day (Figure 1). The diverted trip experiences the widest range with a low of 0.8 in the midmorning hours to a high of 2.0 in the evening. The primary trips vary at a different pattern with trip uniformity (i.e., low CV) in the p.m. peak rush hour. The weighted composite CV is also shown in Figure 1; its weighting method is based on the relative proportions of primary and diverted trips for the respective period.

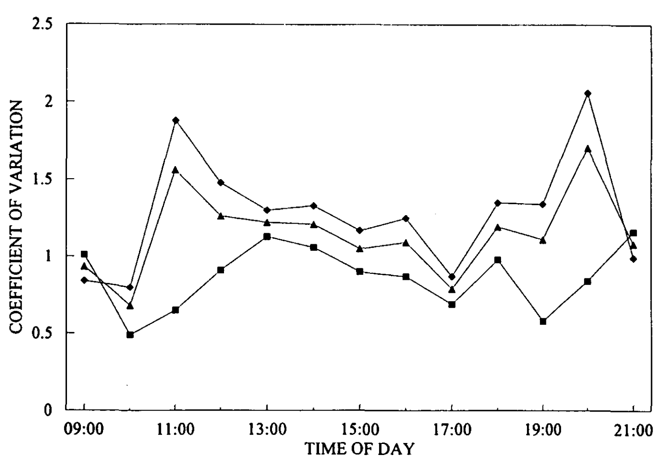

FIGURE 1 Coefficient of variation: hourly variation. (Note: These values are not statistically reliable for inference for some early a.m. and late p.m. hours because of small sample returns.)

Response Rate

A control survey was conducted at the same site exactly 1 year after the first survey to evaluate the response incentive. Whereas in the test survey the average response rate was nearly 30 percent, in the control survey it was 11 percent. This rate was similar to that of a pretest (10 percent) conducted at another site before the original test survey. Although the control survey's percent shares of primary, diverted, and captured trips varied noticeably from those during the same survey period of the first test survey (44, 25, and 31 percent versus 30, 40, and 30 percent, respectively), the weighted average trip length was not significantly different (the T-statistic was −0.9) from that of the 1990 test survey during the same period studied (1:00 p.m. to 7:00 p.m.). Thus, it may be concluded that the same population was sampled both years.

EVALUATION AND APPLICATIONS

Coefficient of Variation

Perhaps one of the significant findings of this research is that the CV for trip length, an important variable in the sample size equation, is different for primary and diverted trip types and varies throughout the shopping hours. The research identifies, for both the total day as well as the various hours of the day, the estimate of the weighted CV. The average CVs estimated for the test site are 0.8 and 1.6 for primary and diverted trips, respectively. The findings may be used to initially determine sample size for both total day surveys or surveys whose goal is to obtain an estimate of trip characteristics for a specific time period (provided both the confidence limits and error range are not constrained within the shortened survey period).

Bias Control

The test survey was specifically structured to evaluate the commonly used roadside (or driveway/exit) sampling technique for its appropriateness in site surveys. Because the driveway exit selection of each survey respondent was recorded during data collection, reduction of the data permitted the identification of trip types and lengths as a function of driveway exit. Table 1 summarizes the day's totals for each. The most revealing result of the data reduction is that the observed percentages of trip types at the driveways are different from that of the parking lot (i.e., the total population). A contingency table (chi-squared) statistical test of the expected and observed returns confirms that there is a significant difference (at a 90 percent confidence level) between the sampling locations. This confirms the potential for intrasite sampling location bias.

As proportioned sampling is not feasible because of the high probability of differing access point selection rates of the

TABLE 1 Trip Type Percentages per Entrance

Sample Location	Primary	Diverted	Captured
Parking Lot	31%	41%	28%
Entrance #1	23%	43%	34%
Entrance #2	23%	49%	28%
Entrance #3	38%	37%	25%

trip types and because prestratification of trip types is virtually impossible, at land development survey sites (especially retail centers that have multiple access points), the roadside interview survey method should not be used except under one (limited) condition, wherein a single access point exists or can be temporarily created for the duration of the survey period.

Second, although the graphs are not shown here, trip type percentages were uniform at one of the site's entrances, but there was considerable temporal variation in the percentages utilizing the other entrances. Because each entrance has a different access geometry and serves different approaches to the site, the temporal variations and the differences in the trip type percentage totals among the entrances suggest that access configuration and traffic congestion may influence route choice, furthering the argument that roadside surveying at driveways of land developments with multiple access points should be avoided. To ensure representative population sampling, questionnaire distribution should be in the parking areas and should be metered hourly on the basis of patronage volumes.

Finally, although the test surveys reveal no data from which the sidewalk (patron) interview method can be proven to have relatively higher inherent biases, a case can be made for the high potential for interview (store tenant) location bias. Theoretically, unless the sidewalk interviews are proportioned among the pedestrian traffic (i.e., stratification of the pedestrian population according to store patronage), significant bias could be introduced into the survey. Although additional research and testing of this hypothesis are necessary for conclusive proof, it stands to reason that highly divergent tenant types will draw patrons of potentially different trip types and lengths, resulting in potentially substantial bias.

Response Incentive

The monetary inducement of $1.00 substantially increased questionnaire response rates from 11 to nearly 30 percent, thus reducing sampling error at a given confidence level. The effective cost reduction of the monetary incentive in the data collection phase was nearly 40 percent per response. The increased response rate makes this method vastly superior to the standard mailback postcard technique.

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REFERENCES

1. A. H. Meyburg and W. Brög. Validity Problems in Empirical Analyses of Non-Home Activity Patterns. In *Transportation Research Record 807*, TRB, National Research Council, Washington, D.C., 1981.
2. *Trip Generation*, 5th ed. Institute of Transportation Engineers, Washington, D.C., 1991.
3. A. R. Kaub. *Standard Least Cost Procedures for Application of Concurrency Management to Transportation Facilities*. Hillsborough County, Tampa, Florida, 1991.
4. C. R. Keller and J. Mehra. *Site Impact Traffic Evaluation (SITE) Handbook*. Report FHWA/PL 85/004. U.S. Department of Transportation, Jan. 1985.
5. A. M. Voorhees and Associates. *NCHRP Report 48: Factors and Trends in Trip Lengths*. HRB, National Research Council, Washington, D.C., 1968.
6. *Traffic Access and Impact Studies for Site Development, A Recommended Practice*. Institute of Transportation Engineers, Washington, D.C., 1991.
7. P. C. Box and J. C. Oppenlander. *Manual of Traffic Engineering Studies*, 4th ed. Institute of Transportation Engineers, Washington, D.C., 1976, pp. 114–118.
8. W. K. Kittelson and T. K. Lawson. Evaluation of Shopping Center Trip Types. *ITE Journal*, Feb. 1987, pp. 35–39.
9. Tindale-Oliver & Associates and JHK & Associates. *Pinellas County Transportation Impact Fee Study*. Pinellas County Metropolitan Planning Organization, Clearwater, Fla., 1990.
10. W. R. McShane and R. P. Roess. Volume Studies. In *Traffic Engineering*, Prentice Hall, Englewood Cliffs, N.J., 1990, pp. 22–110.
11. K. Webb and H. P. Hatry. *Obtaining Citizen Feedback: The Application of Citizen Surveys to Local Governments*, The Urban Institute, Washington, D.C., 1973.
12. M. E. Smith. Design of Small-Sample Home-Interview Travel Surveys. In *Transportation Research Record 701*, TRB, National Research Council, Washington, D.C., 1979.
13. W. E. Oliver. Measuring Travel Characteristics for Impact Fees. *ITE Journal*, Vol. 61, April 1991, pp. 11–15.

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