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16. Abstract <p>Study Number 2-10-71-167, entitled "Urban Travel Forecasting," was a 3-year planning study directed toward providing continuing technical support to the Texas Highway Department in the conduct of urban transportation studies throughout the State. Under this study, assistance was provided in the analysis and forecasting techniques relative to urban transportation studies; the maintenance and modification of computer programs previously developed for and used by the Texas Highway Department; the preparation of additional computer programs; and the implementation of research findings and the use of models and computer programs developed under this study or its predecessors (i.e., Studies 2-8-63-60 and 2-10-68-119).</p> <p>The accuracy of home interview data in estimating zonal trip ends and travel patterns was investigated using 100% survey data from 3 zones. These analyses indicated disturbingly low probabilities of reasonably accurate estimates of either zonal trip ends or travel patterns using traditional sampling rates. These analyses suggest, however, that an estimating equation (regression model or cross-classification rates) based on either disaggregate or aggregate data will provide more reliable estimates of zonal trip ends than the O-D survey directly. These analyses also indicated that significant cost savings could be achieved while still maintaining acceptable accuracy of trip generation estimates through more statistically efficient procedures and the knowledge of experienced analysts. Based largely on these findings, a synthetic study was proposed, designed, and implemented in a cooperative effort between the Texas Highway Department and Texas Transportation Institute.</p>			
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URBAN TRAVEL FORECASTING

by

J. D. Benson
Assistant Research Planner

and

Vergil G. Stover
Study Supervisor

Research Report 167-9F
Final Report

Urban Travel Forecasting
Research Study Number 2-10-71-167

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College Station, Texas

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ABSTRACT

Study Number 2-10-71-167, entitled "Urban Travel Forecasting," was a 3-year planning study directed toward providing continuing technical support to the Texas Highway Department in the conduct of urban transportation studies throughout the State. Under this study, assistance was provided in the analysis and forecasting techniques relative to urban transportation studies; the maintenance and modification of computer programs previously developed for and used by the Texas Highway Department; the preparation of additional computer programs; and the implementation of research findings and the use of models and computer programs developed under this study or its predecessors (i.e., Studies 2-8-63-60 and 2-10-68-119).

The accuracy of home interview data in estimating zonal trip ends and travel patterns was investigated using 100% survey data from 3 zones. These analyses indicated disturbingly low probabilities of reasonably accurate estimates of either zonal trip ends or travel patterns using traditional sampling rates. These analyses suggest, however, that an estimating equation (regression model or cross-classification rates) based on either disaggregate or aggregate data will provide more reliable estimates of zonal trip ends than the O-D survey directly. These analyses also indicated that significant cost savings could be achieved while still maintaining acceptable accuracy of trip generation estimates through more statistically efficient procedures and the knowledge of experienced analysts. Based largely on these findings, a synthetic study was proposed, designed, and implemented in a cooperative effort between the Texas Highway Department and Texas Transportation Institute.

A preliminary macroscopic analysis of the temporary stability of trip generation rates indicates that these rates have been increasing as a result of a greater propensity to travel and changes in socioeconomic characteristics. A preliminary evaluation of induced traffic on new highway facilities suggests that this element may account for a significant portion of the traffic on many new facilities and may partially explain the tendency to underestimate traffic on such facilities.

Key words: Urban transportation studies, origin-destination studies, trip generation, trip distribution, traffic assignment.

SUMMARY

Study 2-10-71-167, entitled "Urban Travel Forecasting," was a three-year planning study directed toward providing technical support to the Texas Highway Department in the conduct of urban transportation studies throughout the State. The activities under this study generally fall into two categories: analytical activities and computer related activities.

The following summarizes some of the more important or larger analytical activities and their findings:

- The trip end analysis of the San Antonio 100% data indicated that significant cost savings could be achieved in urban transportation studies while maintaining acceptable estimates of trip generation.
- The travel pattern analysis of the San Antonio 100% data indicated that disturbingly large expected error ranges are associated with zonal travel pattern estimates from the home interview survey.
- A preliminary investigation of induced traffic on new highway facilities indicated that this element may account for a significant portion of the traffic on many new facilities and may, thereby, partially explain the tendency to underestimate traffic on such facilities.
- A preliminary macroscopic analysis of the temporal stability of trip generation rates indicates that these rates have been increasing as a result of a greater propensity to travel and changes in socioeconomic characteristics.
- A synthetic study was proposed, designed and implemented in a cooperative effort between the Texas Highway Department and the Texas Transportation Institute.

The computer related activities included the maintenance and modification of computer programs developed under this study or its predecessor (i.e., Study 2-10-68-119); the preparation and maintenance of operating manuals and program documentation manuals; the preparation of additional computer programs to meet the changing needs of the Texas Highway Department; and assistance in the use of the models and computer programs developed under this study and its predecessor. In addition, a multiple path assignment procedure was developed and implemented in both the Texas Large Network Package and the Texas Small Network Package.

IMPLEMENTATION STATEMENT

Three major computer program packages (i.e., the Texas Trip Distribution Package, the Texas Large Network Package, and the Texas Small Network Package), developed under this study and its predecessor, and maintained under this study, have been adopted by the Texas Highway Department and are currently being used in their urban transportation studies.

Based largely on the findings of the analyses of the accuracy of home interview survey data in estimating zonal travel characteristics, the Texas Highway Department has abandoned the traditional home interview survey in its urban transportation studies and has adopted a new "synthetic" study approach. The synthetic study in the Houston-Galveston urban area was proposed, designed, and implemented in a cooperative effort between the Texas Highway Department and the Texas Transportation Institute under this study. It has been estimated that the implementation of the synthetic study approach in the Houston-Galveston study has resulted in a net savings to Texas Highway Department of approximately \$1,000,000.

INTRODUCTION

Study Number 2-10-71-167, entitled "Urban Travel Forecasting," is a continuing cooperative research effort between the Texas Transportation Institute and the Texas Highway Department. The 3-year study was preceded by Studies 2-8-63-60 and 2-10-68-119. A number of research elements undertaken but not completed under Study 119 are included in the research effort continued under Study 2-10-71-167.

The primary concern of Study Number 2-10-71-167 (as with its predecessors' studies) was to provide technical support for the continuing activities of the Texas Highway Department in the conduct of the several urban transportation studies throughout the State of Texas. Therefore, the project objectives were formulated and a work program was executed so as to be of maximum value in the conduct of the several urban transportation studies in the State. Since the project was to be attuned to the day-to-day performance of urban transportation studies, it was funded and administered as a planning study rather than as a research study.

The close liaison between the TTI research staff and personnel of the Planning-Survey Division of the Texas Highway Department throughout the course of the study was an essential ingredient. Through this contract, the research staff was continually aware of the operational problems and practices of the Highway Department. Similarly, the operational staff was involved in the research, development, and evaluation from the time work on an individual task was initiated. This relationship has led to exceptionally high implementation and utilization of the study findings; in most instances, research findings were applied and used in the Highway Department's operation well before drafts of the reports were developed.

Problem Statement

The Texas Highway Department makes extensive use of computer program packages developed under the cooperative research program between the Highway Department and the Texas Transportation Institute. Continued maintenance of these programs is essential in order to meet the changing needs of

the Texas Highway Department, and to correct problems resulting from changes in the Operating System in use with the Department's computers of those undetected in previous applications.

Analysis techniques and study procedures evaluated under this program have also been widely implemented. It was anticipated that further use of these programs and techniques would give rise to new problems in program maintenance and application of findings.

The increased cost of conducting current O-D Surveys, together with the increasing reluctance on the part of citizens to cooperate in such surveys created a need for procedures which have considerably smaller data requirements. Previous research under Study 2-10-68-119 suggested that equally reliable results might be obtained by using available data models previously developed, together with a much less extensive data collection. It was believed that such "synthetic" studies could materially reduce the cost of the urban transportation study.

Adoption of the revised study procedures necessitates the further joint analysis and comparison of survey information and data previously collected. Such analysis is necessary to determine the appropriate trip generation rates for the several urban areas. It is also necessary to analyze the available data in order to estimate the expected future change in trip generation rates.

Objectives

The objectives of Study 2-10-71-167 were changed during the course of the study. The first 4, listed below, were the objectives for the first year of study. During the second year of the study, it was formally agreed that objective 1 be eliminated; objective 5 was added for the third year of the study. The objectives for Study 2-10-71-167 were:

1. Evaluation of transit operating and usage characteristics, existing and future, for use by the Texas Highway Department for application in urban areas within the State of Texas. (This objective was eliminated during the second year of the study.)

2. Development and evaluation of procedures and techniques for the conduct of urban transportation studies utilizing a greatly reduced inventory of travel information.
3. Initial investigation of the increased traffic induced by substantial improvements in urban transportation systems.
4. Assistance to the Texas Highway Department in the analysis and forecasting techniques relative to urban transportation studies; particularly with respect to:
 - a. The maintenance of computer programs previously developed for and used by the Texas Highway Department.
 - b. The preparation of additional computer programs that may be needed or desirable for more efficient use of implementation of programs and analysis techniques previously developed.
 - c. The implementation of research findings and the use of models and computer programs developed or evaluated under previous research (i.e., studies 2-8-63-60 and 2-10-68-119).
5. Analyze trends in trip generation and to develop procedures and techniques to conveniently estimate existing and forecast future trip ends (both person and vehicle) within the framework of synthetic transportation studies.

Of the 5 objectives, objective 4 was the primary objective, since, as previously noted, the primary concern of the study was to provide technical support for the continuing activities of the Texas Highway Department in the conduct of the several urban transportation studies throughout the State.

In addition to these objectives, there were substantial carry-over activities from Study 119 to be completed under Study 167. These activities included:

1. Three major computer program packages were essentially developed under Study 119 (i.e., the Texas Large Network Package, the Texas Small Network Package, and the Texas Trip Distribution Package). At the initiation of Study 167, there were modifications necessary to conform to later versions of the IBM Operating System, and improvements were being made in the packages. In addition, both operating manuals and program documentation manuals for the packages needed major revisions or needed to be developed under Study 167.

2. The trip end analysis of the San Antonio 100% data was initiated under Study 119 but remained to be completed under Study 167. In addition, the travel pattern analysis of the 199% data was carried over to be performed under Study 167.

While these were carry-over activities from Study 119, they represent significant levels of effort under Study 167.

Significant Accomplishments

While there were numerous accomplishments under this study, the following briefly summarizes some of the more important or larger activities:

1. The Texas Highway Department was provided with such support that normal operational activities relative to the processing of Urban Transportation study data were maintained.
2. A synthetic study was proposed, designed, and implemented in a cooperative effort between the Texas Highway Department and the Texas Transportation Institute.
3. A preliminary investigation of induced traffic on new highway facilities indicated that this element may account for a significant portion of the traffic on many new facilities and may, thereby, partially explain the tendency to underestimate traffic on such facilities.
4. A preliminary analysis of the temporal stability of trip generation rates was performed. The results of this analysis indicate that trip generation rates have been increasing as a result of a greater propensity to travel and changes in socioeconomic characteristics.
5. The trip end analysis of San Antonio 100% data was completed. The results of this analysis suggest that significant cost savings can be achieved in urban transportation studies while maintaining acceptable estimates of trip generation.
6. The travel pattern analysis of the San Antonio 100% data was performed. The results of this analysis indicate disturbingly large expected error ranges associated with zonal travel pattern estimates from the home interview survey.
7. A multiple-path assignment procedure was developed and implemented in both the large and small network assignment packages.
8. Major modifications were made in the Texas Trip Distribution Package which significantly improved the algorithm used for trip distribution.
9. Major revisions were made in the operating manuals for both assignment packages prior to their publication.

10. Detailed program documentation manuals were prepared for both assignment packages.
11. An operating manual and a program documentation manual were prepared for the trip distribution package.

SUMMARY OF STUDY ACTIVITIES

Due to the operational nature of Study 2-10-71-167, the study activities were primarily directed to the provision of continuing support to the Texas Highway Department in the conduct of ongoing urban transportation studies. Although the activities generally shared this common goal, the activities, themselves, were quite varied. The purpose of this section is both to provide a summary of these activities as well as to provide a summary of salient findings of the analyses.

Induced Traffic

When new facilities are opened that provide a significant improvement in accessibility (reduced travel time) within an area, the resulting traffic volumes are often seriously underestimated. The magnitude of this error is reflected in the example cases cited in Table 1.

TABLE 1 - EXAMPLES OF TRAFFIC VOLUMES EXCEEDING FORECASTS

Location	Projected Traffic		Measured Traffic	
	Year	ADT	Year	ADT
Houston: I 610 across Buffalo Bayou	1980	100,500	1970	129,000
Dallas: I 20 across Downtown	1985	70,000	1970	79,000
Waco: FM 3051 across Bosque River	1970	1,660	1970	6,020
	1985	4,110		

Future traffic on a new highway facility can be divided into the following six components for analysis and forecasting purposes:

1. Diverted Traffic - Trips currently being made on other streets and highways that will be diverted to the new, or improved facility.
2. Converted Traffic - Trips currently being made on other modes of transportation that will be converted to the new facility.

3. Growth Traffic - Increased volumes of traffic due to population growth of the urban area; with the increased population exhibiting the same average trip generation rates.
4. Developed Traffic - Increased traffic volumes due to changes in the land use within the travel corridor served by the new facility. This is an element of growth traffic but it is of such a unique nature in relationship to the new facility that it merits specific identification.
5. Cultural Traffic - Changes in traffic resulting from a change in propensity for travel due to socioeconomic characteristics of the population. This traffic is similar in nature to, and is often included with, growth traffic. Cultural traffic, however, results from changes in customs, cultural habits, and life styles which influence the number of trips made by each person.
6. Induced Traffic - New trips that are made because of the added convenience afforded by the new facility (increased accessibility).

Existing survey and forecasting techniques consider the first four components of future traffic. The Texas Highway Department considers the fifth component (cultural traffic) through the forecasting of increased auto ownership and use. However, present techniques do not account for induced traffic on a new facility.

Recognizing the need to include induced traffic in travel forecasts, the Texas Highway Department approved an analysis of induced traffic as part of Study 2-10-71-167. The following provides a summary of the findings of this analysis.

Existing survey and forecasting techniques do not always adequately estimate the volume of traffic that will use a new facility--especially when a much higher level of service is made available by the new facility. It is suspected that much of this error lies in a failure of properly accounting for the induced traffic component. A better understanding of induced traffic is needed if procedures are to be developed that will avoid such underestimates in the future.

Induced traffic can be expected to occur within a few months after the facility is opened so that it can be easily separated from growth traffic or developed traffic. In other words, traffic using the new facility in the first few months might be expected to be a combination of diverted, converted, or induced traffic. However, construction of a freeway usually

takes 3 to 5 years. During this time, new shopping centers, office complexes, or apartment buildings may be constructed along the route and timed to open simultaneously with the freeway. Thus, a part of what appears to be "induced traffic" may be "developed traffic." Efforts to identify the induced traffic component on a new facility must consider, therefore, recent developments in the area.

Another factor that complicates the identification of induced traffic is that some of it may occur on older facilities where the congestion has been relieved by the new facility. This can be accounted for by using traffic measurements taken in the entire travel corridor before and after the opening of the new facility.

Induced traffic could be more precisely identified if entire new facilities were opened at once, resulting in a sudden and dramatic change in the degree of accessibility for a large segment of an urban area. Examples of such major changes would include the opening of a complete beltway in an urban area where circumferential travel had been difficult, or the simultaneous opening of a number of miles of diagonal freeways in a developed area with a gridiron arterial system. New facilities are usually constructed and opened in relatively short sections that, by themselves, do not produce drastic changes in accessibility. Thus, such induced traffic as does occur is difficult to identify and measure.

Macroscopic Analyses of Induced Traffic

Fifteen possible locations were considered for a study of induced traffic from which 8 were selected for further analyses. These 8 locations represent various types of facilities in several cities in Texas.

For each of these 8 locations, total corridor traffic volumes were plotted for several years before and after the opening of the new facility. The growth trend established prior to the opening of the facility was projected and compared to the actual traffic recorded in the total corridor after the facility was opened. The differences between the projected line of previous trends and the measured traffic was considered to be "apparent induced traffic." Efforts were then made to determine the presence or absence of complicating factors such as changes of land development adjacent to the facility during construction.

Two of the 8 locations presented in Table 2 show no indication of induced traffic. The "apparent induced traffic" component in the other corridors ranged in magnitude from 4,000 vehicles per day to 25,000 vehicles per day, and constitute 5% to 21% of the corridor volume. If all of the "apparent induced traffic" was assumed to occur on the new facility, it would constitute 27% to 67% of the total traffic on the new facility.

The results indicate that induced traffic, or at least the "apparent induced traffic," can be a very significant portion of the traffic on a new facility. This component of traffic appears to be even more significant than was anticipated prior to the study.

Results of these analyses further indicate that the following 2 conditions must exist before a substantial amount of induced traffic will occur on a new facility:

- Major Changes in Accessibility - the off-peak travel time must be reduced significantly.
- Latent Demands Exceed Existing Capacity - the existing facilities have insufficient capacity so that they are acting as bottlenecks.

Based on the results of these analyses, a macroscopic approach was developed which provides a means to evaluate induced traffic based on readily available data. This macroscopic technique utilizes a separation index and a congestion index (representing two factors that influence induced traffic) to determine the amount of induced traffic that is likely to occur on a new facility. Although the precision of the numerical values used in this approach can be improved upon, the approach is believed to be valid and suitable for interim implementation until better data become available. Incorporation of this step into existing traffic forecasting procedures should result in significantly better estimates of future traffic on those facilities that have the potential for induced traffic.

A more detailed account of these analyses and findings are provided in Research Report 167-5, entitled "An Evaluation of Induced Traffic on New Highway Facilities."

TABLE 2: SUMMARY OF RESULTS

			Traffic Volumes After Opening New Facility		"Apparent Induced" Traffic Component		
City	New Facility	Date Opened	Total Corridor	Facility	Magnitude	% of Traffic In Corridor	% of Traffic On New Facility
1. Houston	IH 610 Across Buffalo	1967	150,000	75,000	20,000 vpd	12%	27%
2. Houston	IH 10 near Shepherd	1969	400,000	65,000	0	0	0
3. Dallas	IH 20 across Downtown	1966	170,000	72,000	35,000	21%	49%
4. Ft. Worth	Texas 121 from Riverside to Beech	1964	35,000	13,500	5,000	15%	37%
5. Austin	1st Street Bridge	1954	50,000	9,000	0	0	0
6. Austin	IH 35 across Colorado River	1962	95,000	22,000	10,000	10%	45%
7. Waco	FM 3051 across Brazos River	1970	82,000	6,000	4,000	5%	67%
8. Dallas - Ft. Worth	Turnpike	1958	43,000	16,000	8,000	20%	50%

Temporal Stability of Trip Generation Rates

At the request of the Texas Highway Department, a preliminary macroscopic evaluation of temporal stability of trip generation rates in Texas cities was performed. This macroscopic analysis is essentially a prelude to the detailed trip generation analyses proposed under Objective 5 of Study 2-10-71-167. The following summarizes the preliminary evaluation.

Available travel data indicate that per capita trip generation rates for urban areas in Texas have been increasing. Two general components contribute to increased per capita travel:

- upward shifts in socioeconomic status; and
- an increased propensity to travel. This increased propensity to travel represents changes in travel demand over time within any one socioeconomic level resulting from a changing life style.

In identifying time trends in trip generation rates, 2 different levels of analysis were performed using conveniently available data. The first utilized general indicators of statewide urban travel trends such as urban vehicle miles of travel, urban population, etc. The second involved a study of the different per capita rates of trip generation determined in the various origin-destination surveys conducted in Texas. The annual screenline counts made by the Texas Highway Department were also utilized in this level of analysis.

Analysis of Statewide Travel Data

Between 1960 and 1970, urban vehicle miles of travel in Texas increased at a rate of approximately 6% per year. This increase may be attributed to:

- increases in urban population;
- increases in average trip length (all trip purposes);
- increases in auto availability per capita; and
- increases due to a greater propensity to travel.

Urban vehicle-miles per urban resident increased at an annual rate of 4% between 1960 and 1970; this increase appears to be the result of greater per capita auto availability and a greater propensity to travel. Auto

availability, which is a function of increases in licensed drivers per capita and registered vehicles per capita, increased at an average 2.5% per year. Thus, the propensity to travel appears to be increasing at a statewide average rate of 1.5% per annum.

Annual screenline counts were also used to obtain an additional indication of historical trends in per capita trip generation. The results of these analyses indicate that screenline crossings per urban resident increased at an annual rate of approximately 3.7%. The relatively close agreement between this rate and that obtained from the analysis of urban vehicle miles of travel suggests that, as a statewide average, trips by urban residents have been increasing significantly during the past decade.

The propensity to travel is a dynamic quantity and is subject to significant change over time. For planning purposes, it appears reasonable to assume that the propensity to travel, or at least the desire to make more trips, will continue to increase in the future at about the same rate as in the past, or at an annual rate of approximately 1.5%.

Auto availability per capita, which represents the combined effect of licensed drivers per capita and registered vehicles per capita, historically has increased more rapidly than population. Extrapolation of historical trends suggests that, by 1980 a saturation level of auto availability may be expected to occur in urban areas within Texas. As a result, this travel component is estimated to increase at an annual rate of 1.2% between 1970 and 1980. After about 1980, this component is not expected to contribute to further increases in per capita trip generation.

Therefore, it is estimated that, on a statewide basis between 1970 and 1980, person trips per person will increase at an annual rate of 2.7%; 1.5% of this increase is due to a greater propensity to travel, and 1.2% increase results from greater per capita auto availability. From 1980 to 2000, it appears that person trips may increase to approximately 1.5% per year; all of this increase is the result of a greater propensity to travel.

Future increases in per capita trip generation may be expected to result from increased auto availability and a greater propensity to travel. Based on a review of historical travel data, it is estimated that the propensity to travel, or the desire to increase individual mobility, will

increase at a statewide average annual rate of 1% for the large urban areas, and at 2% for the smaller urban areas. With the available data, it is not possible to precisely quantify these rates of increase for individual urban areas.

Trends in Individual Urban Areas

Comparison of internal person trips per person (as determined in Texas origin-destination surveys) by study year indicates an average statewide increase in per capita trip generation of about 4% per year. Stratification of these data indicates that the following variables assist in explaining the variation in trip-making rates between the different urban areas:

- year of study;
- population;
- geographical location;
- per capita auto ownership; and
- per capita median income.

A review of the data suggests that an urban area population of approximately 175,000 represents a dividing point between urban areas exhibiting travel patterns characteristic of "large" and "small" urban areas. Geographical location*, which, for Texas cities also reflects socioeconomic differences, affects per capita trip generation. Residents of North Texas cities apparently make more trips than residents of South Texas cities, as indicated by Figure 1. However, the rate of increase in trip making seems to be much greater in South Texas cities.

"Geographical location," which reflects socioeconomic differences, also appears to explain some of the variations in trip-making rates between the large urban areas (Figure 2). The historical rate of increase in per capita trip generation appears to average about 3% per year for all large urban areas.

*Geographically, Texas Study areas can be divided into "North" cities and "South" cities. Considered as South cities are Brownsville, Corpus Christi, El Paso, Harlingen-San Benito, Laredo, McAllen-Pharr, and San Antonio. The remaining urban study areas are classified as North Texas cities. Median per capita income and auto ownership are higher in the North Texas cities.

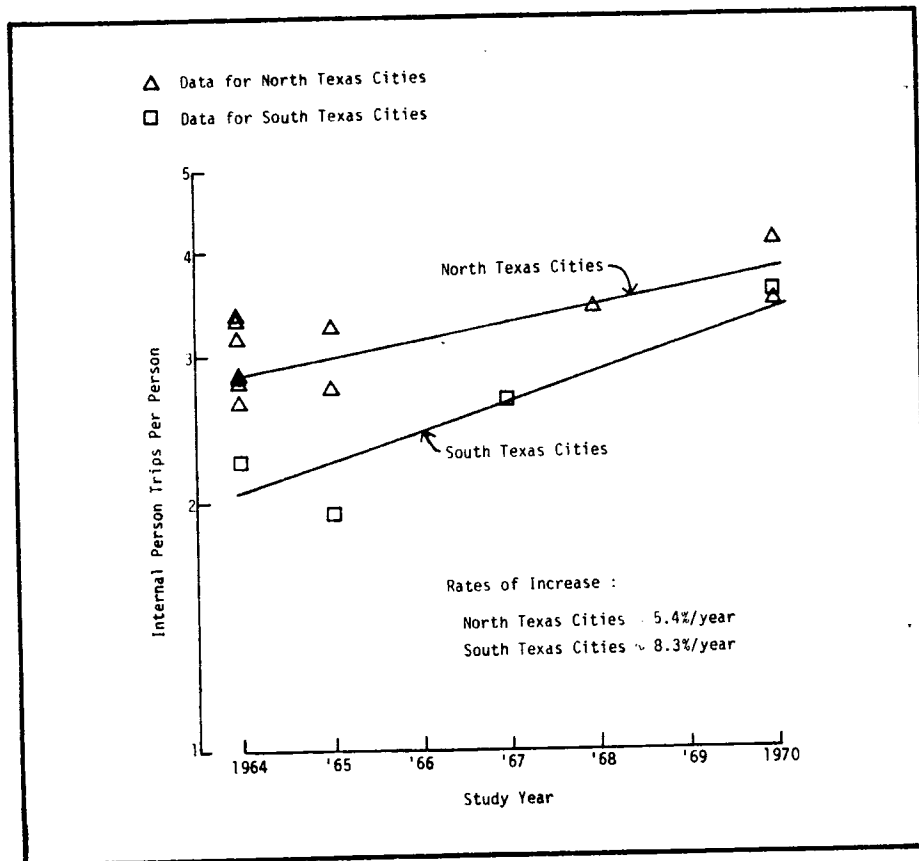


FIGURE 1: EFFECT OF GEOGRAPHICAL LOCATIONS ON PER CAPITA TRIP GENERATION RATES, URBAN AREAS WITH POPULATION < 175,000

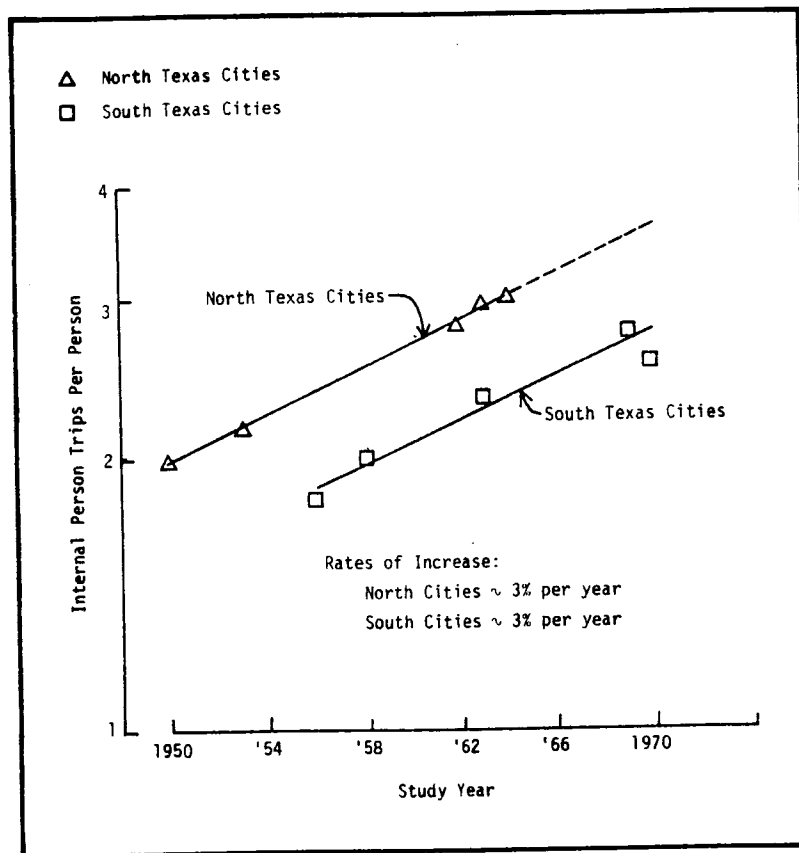


FIGURE 2: EFFECT OF GEOGRAPHICAL LOCATION ON PER CAPITA TRIP GENERATION RATES, URBAN AREAS WITH POPULATION > 175,000

Increases in average per capita income also relate to historical shifts in trip making for the large urban areas. Figure 3 suggests that change in average per capita income might be used as a rough approximation in estimating the increase in trip generation rates.

Conclusions

The analyses suggest that internal person trips per person and internal auto-driver trips per person have been increasing at a more rapid rate than previously supposed. Continued increases in per capita trip making can be anticipated; however, a decline in the rate of increase in per capita trip making is expected, as a saturation level of vehicles per capita is projected within urban areas by about 1980.

A detailed account of these analyses and findings is reported in Research Report 167-6, entitled, "A Preliminary Evaluation of the Temporal Stability of Trip Generation Rates."

Accuracy of Home Interview Data

The purpose of these analyses was to investigate the accuracy of sampled home interview data in estimating zonal trip generation and travel patterns. These analyses are unique, in that the data base used consisted of a 100% survey of three adjacent zones located in the north central portion of San Antonio. The zones were selected on the basis of their apparent homogeneity and nonunique characteristics. Their general appearance typifies a lower-middle class neighborhood of single family dwelling units typical of mid- and late-1950 construction. The data were collected by the Planning Survey Division of the Texas Highway Department during the home interview phase of the San Antonio-Bexar County Urban Transportation Study.

Trip Generation Analyses

The general data analysis confirmed the homogeneity of the travel characteristics of the zones. Large sets of repeated random samples were drawn at various sampling rates from each of the 3 zones and the combined

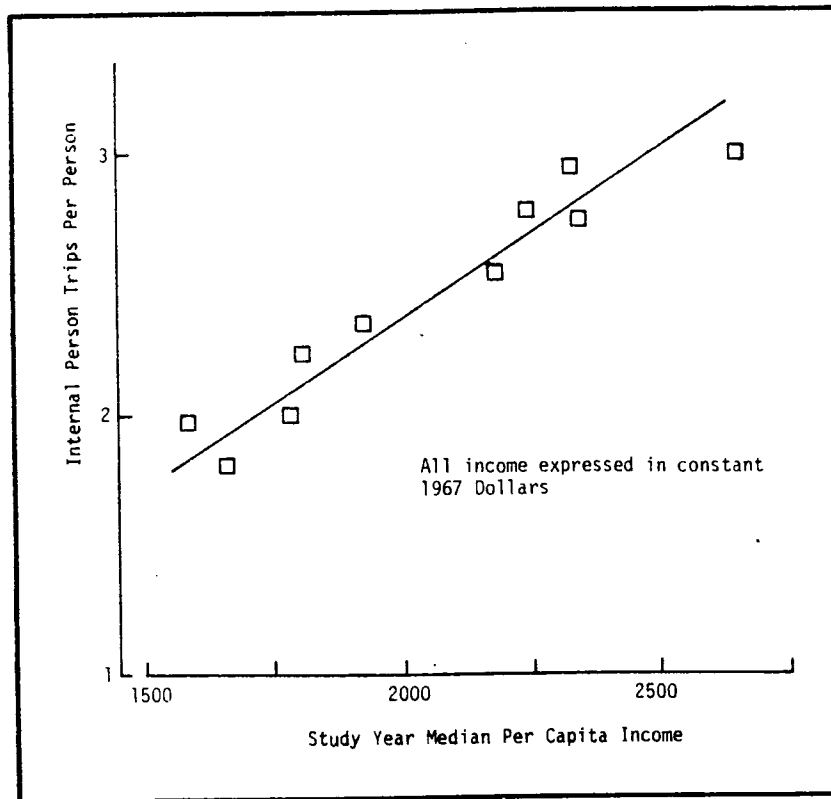


FIGURE 3: EFFECT OF MEDIAN INCOME ON PER CAPITA TRIP GENERATION RATES, URBAN AREAS WITH POPULATION > 175,000

area (i.e., the 424 occupied dwelling units comprising the 3 zones). These sets of random samples were used to verify the basic assumptions and general applicability of a set of theoretical relationships between sample size and the expected error of estimation.

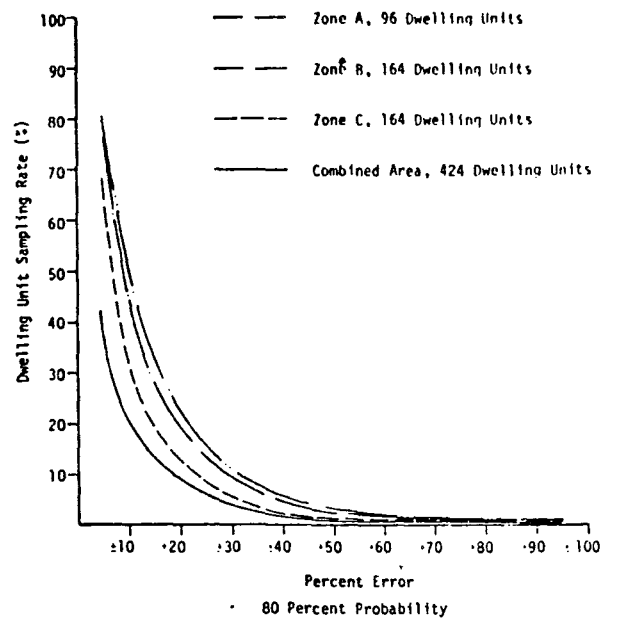
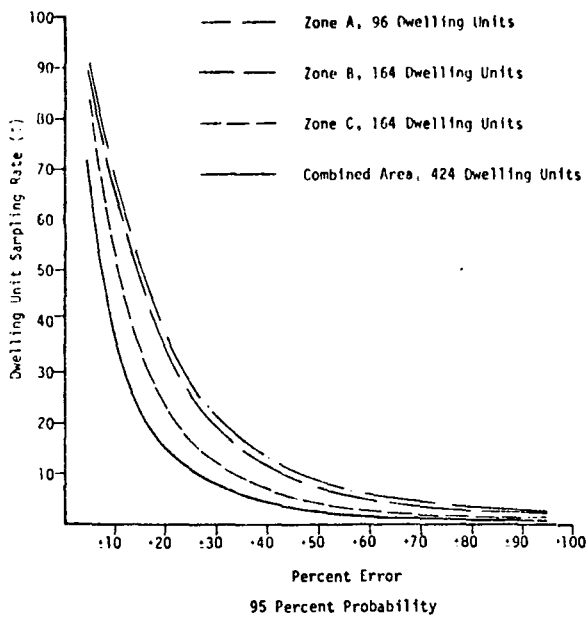
Disaggregate Analyses

The analysis of disaggregate data was directed toward the accuracy of home interview data in estimating the population mean (i.e., the mean trips per dwelling unit) and the population variance (i.e., the variance between dwelling units in trip productivity). Having population data (i.e., the variance, the coefficients of variation, etc.) allows the direct application of formulas from statistical theory to quantitatively study the relationship between the sampling rate and the expected percent error relative to the estimation of the mean trips per dwelling unit. For each of the 8 trip categories, as well as for each of the 3 zones and the combined area, the required sampling rates at the 80% and 90% probability level were computed for error ranges from $\pm 5\%$ to $\pm 95\%$. Figures 4 and 5 illustrate the results of these computations for home-based work and nonwork trips.

A number of general observations become apparent from careful inspection and comparison of such data for the various trip purposes; these include:

- Rather large sampling rates are required to estimate the mean trips per dwelling within reasonable ranges of error, even at the 80% probability level.
- Increasing the sampling rate decreases the error ranges at a decreasing rate. For example, increasing the sampling rate from, say, 5% to 10% results in a larger reduction in the error range than increasing the sampling rate from, say, 55% to 60%.
- As expected, increasing the zone size tends to reduce the expected percent error ranges associated with any sampling rate. From statistical theory, it may be demonstrated that, if the coefficient of variation and the sampling rate are assumed to remain constant, the expected percent error will vary inversely with the square root of the zone size (i.e., the number of occupied dwelling units). From statistical theory, it may likewise be observed that, *ceteris paribus*, the magnitude of the expected error relative to the mean will also vary inversely with the square root of the zone size.

PERSON TRIPS



AUTO-DRIVER TRIPS

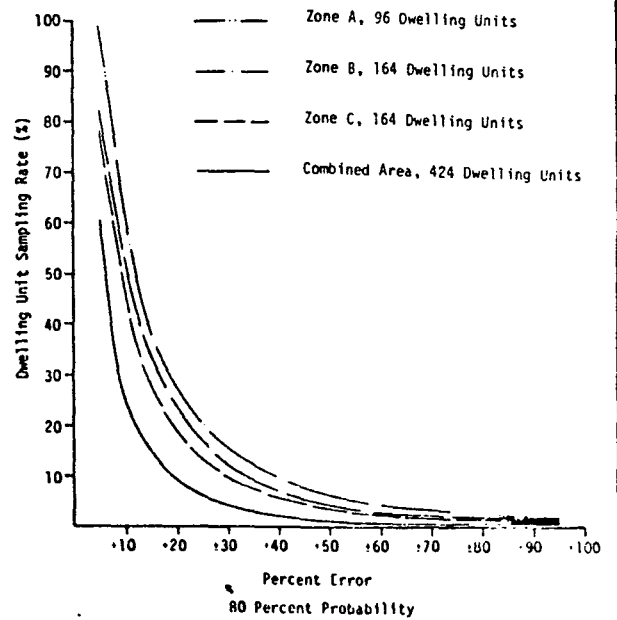
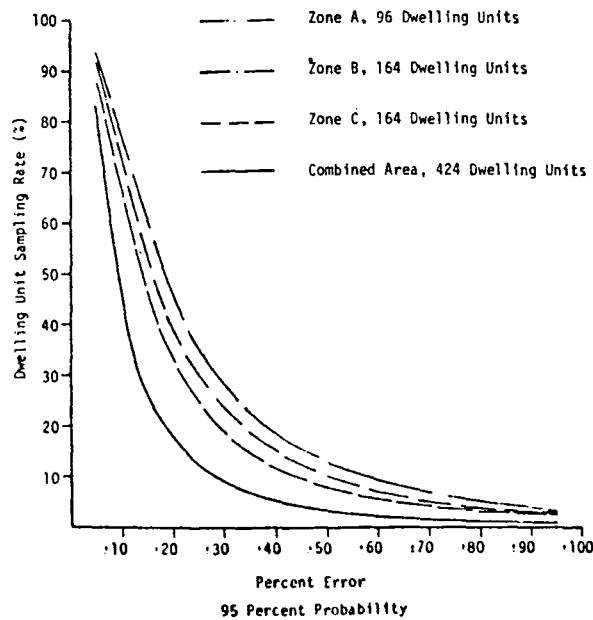
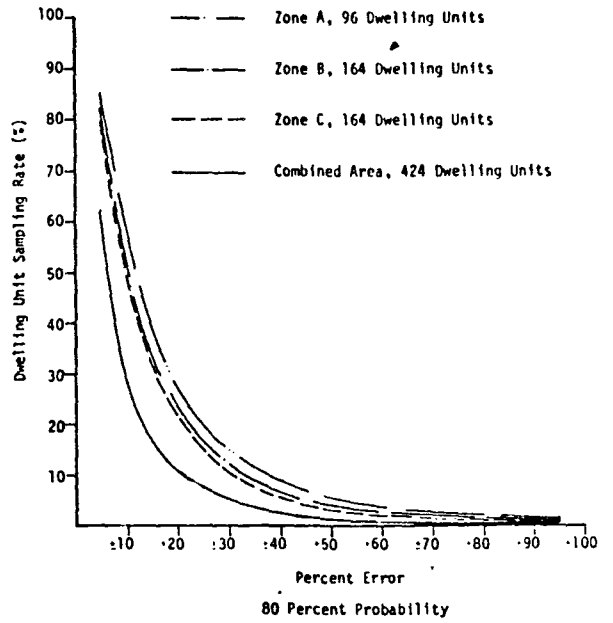
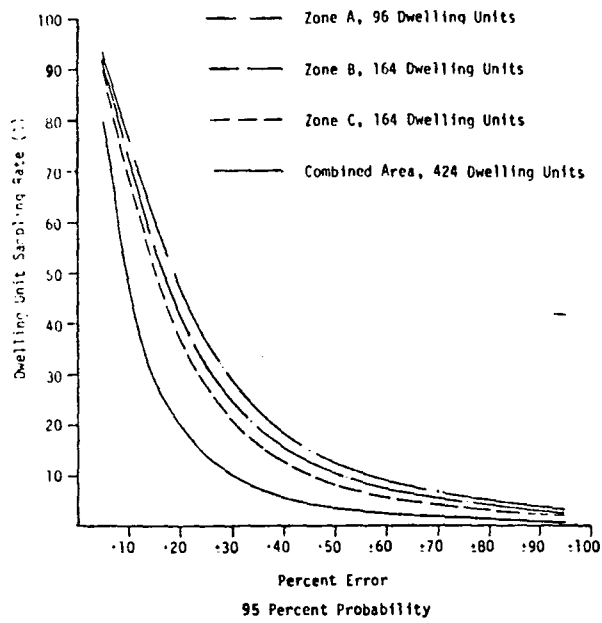


FIGURE 4: MARGIN OF ERROR VERSUS SAMPLING RATE FOR HOME-BASED WORK TRIPS

PERSON TRIPS



AUTO-DRIVER TRIPS

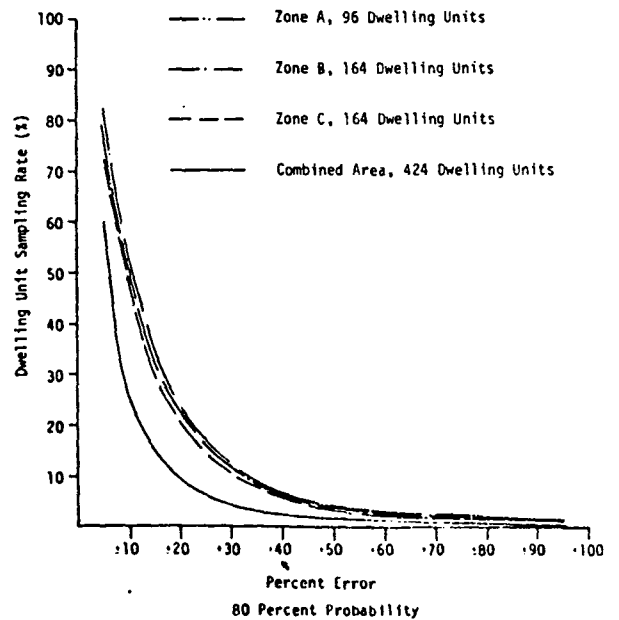
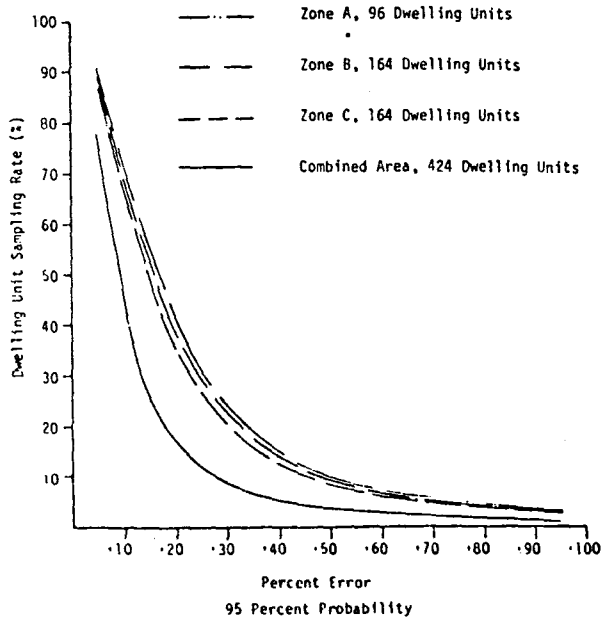


FIGURE 5: MARGIN OF ERROR VERSUS SAMPLING RATE FOR HOME-BASED NON-WORK TRIPS

- The expected percent error ranges, as well as the magnitude of the error for the estimation of auto driver trips, are generally less than those for the estimation of person trips. From statistical theory, it may be demonstrated that, *ceteris paribus*, the expected percent error will vary directly with the population coefficient of variation. Therefore, this observation essentially suggests that the coefficients of variation for the auto driver trips are generally less than those for person trips. Also, it may be demonstrated from statistical theory that, *ceteris paribus*, the expected magnitude of the error range will vary directly with the population variance. This, of course, suggests that both the population variance and coefficient of variation for auto driver trips are generally less than those for person trips.

The results indicate that, at both the 80% and 95% probability levels, large error ranges (i.e., a large variance of estimates) may be expected when using traditional sampling rates in estimating the mean trips per dwelling unit for a given zone. Table 3 summarizes the expected error ranges in terms of the mean trips per dwelling unit for the Combined Area at the 95% probability level. The disaggregate analysis further suggests that either disaggregate cross classification or regression analyses will provide a more reliable estimate of zonal trip ends than the simple expansion of the zone's mean trips per dwelling unit observed from the O-D survey.

Analysis of the variance of estimates of the population variance suggests that the estimates of the population variance using traditional sampling rates are not even of sufficient accuracy to yield reasonable estimates of sample size requirements.

Aggregate Analyses

The analysis of aggregate zonal data was directed toward the accuracy of home interview data in estimating the zonal trip generation (i.e., the number of trips produced by the zone). The relationship between the sampling rate and the expected percent error is applicable to the estimation of zonal trip generations as well as the mean trips per dwelling unit. The data previously summarized in Figures 4 and 5, therefore, are applicable to the estimation of zonal trip generations. As in the disaggregate analyses, these results indicate that, at both the 80% and 95% probability

TABLE 3: SUMMARY OF EXPECTED ERROR RANGES IN TERMS OF THE MEAN TRIPS PER DWELLING UNIT FOR THE COMBINED AREA AT 95% PROBABILITY LEVEL

<u>Trip Category</u>	<u>Expected Error Ranges</u>	
	<u>5% Sample</u>	<u>12.5% Sample</u>
Home-based Person Trips (7.59 trips/dwelling unit)	5.0 to 10.2	6.0 to 9.2
Home-based Auto Driver Trips (4.93 trips/dwelling unit)	3.4 to 6.5	4.0 to 5.9
Home-based Work Person Trips (2.0 trips/dwelling unit)	1.3 to 2.7	1.6 to 2.4
Home-based Work Auto Driver Trips (1.61 trips/dwelling unit)	0.9 to 2.3	1.2 to 2.0
Home-based Nonwork Person Trips (5.59 trips/dwelling unit)	3.2 to 8.0	4.1 to 7.1
Home-based Nonwork Auto Driver Trips (3.32 trips/dwelling unit)	2.0 to 4.7	2.5 to 4.1
Nonhome-based Person Trips (2.07 trips/dwelling unit)	0.7 to 3.4	1.3 to 2.9
Nonhome-based Auto Driver Trips (1.62 trips/dwelling unit)	0.7 to 2.6	1.0 to 2.2

levels, large error ranges may be expected when using the traditional sampling rate in estimating zonal trip ends. Table 4 summarizes the expected error ranges in terms of the zonal trip generations for the Combined Area (i.e., the 424 occupied dwelling units) at the 95% probability level.

As with the disaggregate analysis, the aggregate analysis suggests that an estimating equation (regression model or cross classification rates), based on aggregate zonal data, will provide a better estimate of zonal trip ends than the O-D survey directly. This analysis also indicates that the use of RMS error in evaluating trip generation procedures is questionable.

Implications

It must be emphasized, however, that this does not suggest that the home-interview surveys performed in the past have not been necessary. To the contrary, these surveys provide the extensive travel data upon which the experienced analyst must be able to draw. Further, it does not suggest that home interview surveys should be discontinued. It does suggest a new direction for such surveys involving a limited number of observations which are specifically directed toward monitoring trends, updating travel characteristics, and investigating areas which exhibit unusual characteristics.

In essence, the trip generation analyses of the 100% survey data at both the disaggregate and aggregate levels indicate that significant cost savings can be achieved while still maintaining acceptable estimates of trip generation. Such savings would result from effectively using O-D data already collected and the use of special surveys (involving a limited number of interviews) directed toward monitoring changes in travel characteristics. Acceptable accuracy can be maintained through more statistically efficient use of home interview survey data and the knowledge of the experienced analyst.

Based largely on the findings of these analyses, the Texas Highway Departemnt has discontinued use of the traditional home interview surveys in its urban transportation studies, and has adopted a "synthetic" study

TABLE 4: SUMMARY OF EXPECTED ERROR RANGES IN TERMS OF ESTIMATING THE TOTAL TRIPS FOR THE COMBINED AREA AT THE 95% PROBABILITY LEVEL

<u>Trip Category</u>	<u>Expected Error Ranges</u>	
	<u>5% Sample</u>	<u>12.5% Sample</u>
Home-based Person Trips (3220 trips)	2120 to 4325	2544 to 3901
Home-based Auto Driver Trips (2090 trips)	1442 to 2756	1696 to 2502
Home-based Work Person Trips (850 trips)	551 to 1145	678 to 1018
Home-based Work Auto Driver Trips (681 trips)	382 to 975	509 to 848
Home-based Nonwork Person Trips (2370 trips)	1357 to 3392	1738 to 3010
Home-based Nonwork Auto Driver Trips (1409 trips)	848 to 1993	1060 to 1738
Nonhome-based Person Trips (878 trips)	297 to 1442	551 to 1230
Nonhome-based Auto Driver Trips (685 trips)	297 to 1102	424 to 933

approach. This approach is currently being implemented in the Houston-Galveston Regional Transportation Study (H-GRTS). It has been estimated that the use of this approach has resulted in a net savings to the Texas Highway Department of approximately \$1,000,000, or roughly 75% reduction in the estimated cost of the study using the traditional approach.

A detailed account of the trip generation analyses of the 100% data is reported in Research Report 167-7, entitled, "Accuracy of Trip End Estimates for the Home Interview Survey."

Travel Pattern Analyses

The purpose of these analyses was to evaluate the accuracy of the home interview origin-destination surveys in estimating zonal travel patterns. The analyses focused on zonal interactions, zonal interchange volumes, and trip length frequency. Again, the 100% data from the 3 zones in San Antonio were used as the data base for these analyses. In addition, the sampled home interview survey data for the entire urban area were used in the trip length frequency analysis. The results of these analyses are reported in Research Report 167-8, entitled "Accuracy of Travel Pattern Estimates From the Home Interview Survey." The following briefly summarizes the findings of these analyses.

Interaction Analysis

An interaction is defined as a production zone and an attraction zone which interchange one or more trips. Early trip distribution techniques, such as the FRATAR method, relied heavily on observed interactions from origin-destination data and, therefore, tended to underestimate the number of interactions. The resulting trip matrices may, however, still tend to overestimate the number of interactions. The Texas Trip Distribution Model, developed by Texas Transportation Institute in cooperation with the Texas Highway Department, handles this problem through the use of an interaction constraint. In all cases, zonal interaction is an element of travel pattern which is estimated (either directly or indirectly) in the modeling process.

The 100% data collected for the 3 zones in San Antonio has, therefore, been used to analyze the interaction characteristics of each of these 3 zones as well as the combined area and to investigate the characteristics of sampled interaction data. The following summarizes some of the conclusions drawn from this analysis:

- A general relationship exists between trips and the interactions such, as the production volume for a zone increases, the expected number of interactions will increase at a decreasing rate until the bounding condition (i.e., the maximum number of possible attraction zones) is reached. This relationship varies from zonal structure to zonal structure within a given urban area and from trip purpose to trip purpose for a given urban area and structure.
- As the trip productivity of a dwelling unit increases, the expected number of dwelling unit interactions (i.e., the number of attraction zones with which the dwelling unit is expected to interact) increases but at a decreasing rate.
- The sampling theory generally associated with home interview O-D surveys is not applicable to the estimation of interactions. The expansion of observed interactions for sample data employing traditional sampling rates resulted in very large overestimates of the actual number of interactions for the zones studied.
- The analysis of observed trips and observed interactions indicated that there is an exponential relationship between trips and interactions. Such a relationship might be estimated from sample data and subsequently used to estimate the expected number of interactions for given production volumes.

Interchange Volume Analysis

The production-attraction interchange volume, T_{ij} , is the number of trips produced by zone i which are attracted to zone j and are the principal output of a trip distribution mode. Since an interaction is a zone pair having a nonzero interchange volume, the estimation of interactions is simply the estimation of the number of nonzero interchange volumes associated with a production zone. The number of trips at a given spatial separation is essentially the sum of the interchange volumes for all the zone pairs having a given separation. The following summarizes the conclusions drawn from the interchange volume analysis:

- The characteristics of the interchange volumes associated with the 3 zones and the combined area generally conform with the expected characteristics based on trip distribution theory.

- In urban transportation studies involving a large number of small- to medium-sized zones, such as San Antonio, a large majority of the interchange volumes would generally be expected to be zero. Of the nonzero interchange volumes, a large majority would generally be expected to fall in the volume range of from 1 to 10 trips.
- By using traditional sampling rates, a large majority of the small interchange volumes of 1 to 10 trips may generally be expected to remain undetected by the survey. Those detected by the survey may generally be expected to be substantially overestimated (i.e., an error estimate generally exceeding +2000%). In studies utilizing a large number of small- to medium-sized zones, these small interchange volumes not only account for a majority of the nonzero interchange volumes but account for a substantial portion of the trips.
- Sampling rates of 25% and above would generally be required to obtain estimates of nonzero interchange volumes of fewer trips within $\pm 100\%$ of the 95% confidence level. In studies utilizing small- to medium-sized zones, interchange volumes of 50 and fewer trips will generally account for the large majority of the trips in the urban area.
- Interchange volumes of 100 to 200 trips require sampling rates of greater than 5% to be 95% confident that the estimates of these interchange volumes are within $\pm 100\%$. Empirical data from repeated random samples indicate that, at a 5% sampling rate, an error of 40% to 50% of these estimates will exceed $\pm 50\%$. At a 12.5% sampling rate, 80% to 90% of the estimates will be within $\pm 50\%$ of the actual volume. Thus, even for relatively large interchange volumes, traditional sample sizes are judged to provide only moderate levels of accuracy in estimating interchange volumes.

Trip Length Frequency Analysis

The trip length frequency analysis for the entire urban area focused primarily on the estimation of the mean trip length for the urban area. The results of this analysis suggests that a random sample of approximately 400 dwelling units may generally be expected to yield an acceptable estimate of the mean trip length for an urban area. Since other research (Research Report 2-17-1) indicates that, given the mean trip length, a reasonable estimate of the trip length frequency distribution may be developed, this suggests that a reasonable estimate of the trip length frequency distribution for an urban area may be developed from a random sample of roughly 400 dwelling units.

Synthetic Studies

The increasing cost of conducting origin-destination surveys, together with the increasing reluctance on the part of citizens to cooperate in such studies, created a need for procedures which have considerably smaller data requirements. Analyses of the San Antonio 100% data suggest that equally reliable estimates of trip generations might be obtained by using available data models previously developed, together with a much less extensive data collection. Based on these findings, together with previous research conducted under Study 119, it was believed that a "synthetic" study approach could be designed and implemented which would reduce the data requirements while maintaining equally reliable results.

The "development and evaluation of procedures and techniques for the conduct of urban transportation studies utilizing a greatly reduced inventory of travel information" was included, therefore, as one of the objectives (i.e., Objective 2) for Study 2-10-71-167. The activities under this objective have been joint efforts between TTI staff and THD personnel. The following briefly summarizes the activities under this objective.

Several technical work sessions involving TTI staff and THD personnel were held to discuss the design of the Houston-Galveston Regional Transportation Study (the study tentatively selected for the first major application of the synthetic study approach). The general design of a synthetic study was jointly developed; this design served as the basis for the request (which was approved) to depart from the conventional O-D survey and conduct a synthetic travel study instead.

Following the approval to implement the synthetic study approach in the Houston-Galveston Regional Transportation Study (H-GRTS), several technical work sessions were held with THD personnel to discuss the details relative to the design, data collection, program application, and analysis in a synthetic study. From these meetings, a detailed study design was developed for implementation in the H-GRTS.

To field test the detailed study design, Big Spring was selected by THD as the site for a pilot study. The pilot study not only provided useful experience in the application of the synthetic study approach, but led to a number of refinements in the detailed study design.

Based on the success of the pilot study, it was decided to proceed with its implementation in the H-GRTS. TTI staff have worked closely with THD personnel through all phases of both the pilot study and H-GRTS. These activities include:

- Assistance in the development of trip generation rates.
- Assistance in the calibration and evaluation of trip distribution and traffic assignment results.
- Assistance in numerous minor problems encountered throughout the study.
- Assistance in the review and evaluation of study results.

To date, the existing or base year phase of the study has been completed and the forecast phase is in progress. TTI staff are continuing to work closely with THD personnel in the forecast phase of the H-GRTS. These activities are being continued under Study 2-10-74-17.

The assignment results from the existing or base year analysis are as good or better than those obtained in other studies using conventional study techniques. Indeed, it is felt that the implementation of the synthetic study approach in the H-GRTS has been a complete success. In view of its successful application in the H-GRTS, the synthetic study approach is in the process of being implemented in all urban transportation studies in Texas. It has been estimated that the use of this approach in the H-GRTS has resulted in a net savings to THD of approximately \$1,000,000, and that its implementation in other studies will result in still more cost savings to THD.

Traffic Assignment Packages

The Texas Large Network Package and the Texas Small Network Package were essentially developed under Study 2-10-68-119. The packages were developed under an accelerated development program aimed at maintaining operational capability for the THD in the change-over from the IBM 7094 to the IBM 360 computer system. To expedite this development, several of the auxiliary routines were programmed in FORTRAN which could be, at a later date, reprogrammed in assembly language to improve the operational efficiency of the packages. During their early implementation, however,

the packages were plagued with problems resulting from the numerous and seemingly continual changes in the IBM 360 Operating System. As a result, it became a challenge to simply keep the packages operational. It was necessary, therefore, to delay many of the planned revisions in the packages and to carry-over these program "clean-up" activities under Study 2-10-71-167.

In addition to the program "clean-up" activities, there were the normal program maintenance activities to be accomplished under Study 2-10-71-167. These normal maintenance activities include program modifications to implement new research findings, to provide new or additional information to meet the changing needs of the THD, to expand the program capacities when required to meet the needs of the THD, to implement computationally more efficient algorithms and techniques, to simplify the user requirements, to adapt to changes in the operating system, and to take advantage of changes in the hardware and software available. In essence, the packages are not static but are dynamic in nature requiring a continuing maintenance program. Numerous modifications and improvements were made in both packages during Study 167.

Multiple Path Assignments

A multiple path assignment procedure was developed and implemented in both packages under Study 167. This procedure produces an assignment in which the assigned volumes are in relative balance with traffic counts or else conform to link capacities. This is accomplished through an iterative technique whereby the link impedances are adjusted between iterations. An all-or-nothing assignment is performed for each iteration based on the "current" link impedances.

Generally, the number of iterations to be performed is determined during the iterative process by multiple regression analysis. In practice, 5 iterations are normally performed.

The link impedances are adjusted, based on either the traffic counts or capacities specified in the link data and the assigned link volumes. The user may elect to use either the counts or the capacities. The impedance of those links with an unspecified count or capacity (depending on which option is elected by the user) is never adjusted. When counts

are used, the impedance of each link is adjusted if its assigned volume does not equal its count. When capacities are used, the impedance of each link is adjusted only if its assigned volume exceeds its capacity.

After the iteration process terminates, the assignments are combined to obtain the final weighted multi-path assignment. This weighted assignment is calculated by applying iteration weights (i.e., percentages determined from a multiple regression analysis technique) to the respective assigned link volumes for each iteration and summing.

Manuals

Due to the many operating system problems, as well as the demands for other activities in progress under Study 119, the publication of the operating manuals was delayed pending major revision to be accomplished as carry-over activities under Study 167. The "Operating Manual for the Texas Small Network Package," Research Report 119-1, and the "Operating Manual for the Texas Large Network Package," Research Report 119-2, provide the user with detailed information necessary to execute the various programs comprising each package, including: a description of each program available in the package, the format specifications, the error messages which may be encountered in using the programs, a description of the printed information produced by each of the programs, the data sets used or created by each of the programs, and the necessary operational procedures for using the package.

A major activity under Study 167 was the development of detailed program documentation manuals for the packages. The "Program Documentation Manual for the Texas Small Network Package," Research Report 167-3, and the "Program Documentation Manual for the Texas Large Network Package," Research Report 167-4, are designed to provide data processing personnel with a link between the operating manuals for the packages and the program contained in the packages. Since these manuals describe the internal operations of the computer programs, they are of primary interest only to data processing personnel charged with the responsibility for modifying and maintaining the packages.

Trip Distribution Package

The Texas Trip Distribution Package is a collection of computer programs having considerable flexibility in performing trip distributions. The development of the package was initiated under Study 119, but, due to problems encountered with changes in the IBM 360 Operating System, the development was delayed and subsequently completed under Study 167. The user manuals for the package were developed under Study 167.

Since its completion, the package has undergone major revision and reprogramming to implement improved procedures for trip distribution and to optimize the operation of the package. In addition, normal program maintenance activities were provided under Study 167. The following provides a brief summary of the Texas Trip Distribution Model (featured in the package), the computer requirements, and the manuals available.

Texas Trip Distribution Model

The Texas Trip Distribution Model, which might be described as a constrained interactance model, allows an interaction constraint to be imposed upon the distribution. When the interaction constraint is applied, only a selected subset of the possible attraction zones for a given production zone are allowed to enter into the distribution process. The model applies trip lengths directly in the distribution process and, consequently, does not involve an iterative calibration process. A sector structure may be imposed to permit a statistical analysis for, and correction of, sector interchange bias created by socioeconomic-topographical travel barriers.

Model Formula

Mathematically, the Texas Trip Distribution Model is stated as follows:

$$T = \frac{P_i A_j F_{tij} B_{s_i s_j} E_{ij}}{\sum_{x=1}^n A_x F_{t_{ix}} B_{s_i s_x} E_{ix}}$$

Where:

- T_{ij} = trips produced in zone i and attracted to zone j
- P_i = trips produced by zone i
- A_j = the relative attraction factor for zone j
- $F_{t_{ij}}$ = the relative trip length factor for the separation equal to t_{ij} (note: t_{ij} is the separation between zone i and zone j)
- $B_{s_i s_j}$ = the sector interchange bias factor for the sector containing zone i (noted as s_i) and the sector containing zone j (noted as s_j) which may be used to define socioeconomic-topographical travel barriers which are not otherwise accounted for in the model.
- E_{ij} = the eliminator function which is used to apply the interaction constraint. It is assigned the value of 1 if zone j is eligible to attract trips from zone, otherwise it is assigned the value of zero.

Interaction Constraint

In order to apply the interaction constraint, the user provides a production interaction curve. As is illustrated in Figure 6, this curve is a boundary condition which specifies the maximum number of attraction zones which will be allowed to be considered in the distribution process for a production zone of a given production volume. For each production zone, the subset of eligible attraction zones are selected based on their accessibility to the given production zone. For convenience, the production-interaction curve may be entered as the coordinates of a series of points which are the end points of a collection of line segments which approximate the desired production-interaction curve.

In the distribution process, trips are computed for each eligible zone pair and residual rounding is performed. Due to this residual rounding, the interchange volume of some of the eligible zone pairs may round to zero and the resulting number of interactions (i.e., zone pair combinations with a nonzero interchange volume) will be less than, or equal to, the total number of eligible zone pair combinations.

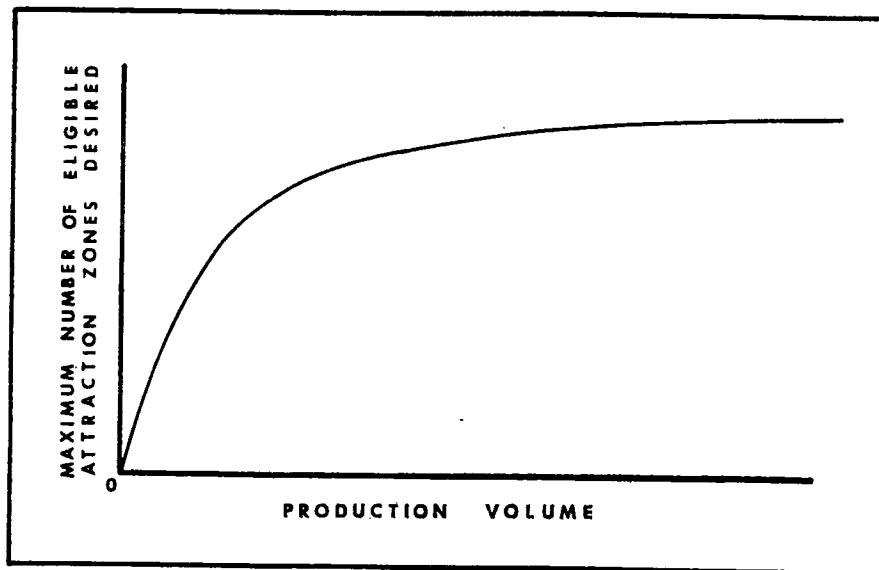


FIGURE 6: INTERACTION CONSTRAINT

Iterative Process

The user may specify the number of iterations to be performed. Normally, 5 or fewer iterations are sufficient. An option is provided in the package whereby the iterative process may be restarted to perform additional iterations without rerunning previous iterations.

The initial values for both the relative attraction factors and the relative trip length factors are computed by the package, based on the interaction constraint and either the desired attraction volumes or the desired trip length frequency. During the iterative process, both the relative attraction factors and the relative trip length factors are adjusted. The adjustment of the relative attraction factors is based on the ratio of the desired volume for a zone versus the resulting attraction volume from the previous iteration. Likewise, the adjustment of the relative trip length factors is based on the ratio of the desired number of trips at a given separation versus the resulting number of trips at that separation from the previous iteration.

Computer Requirements

The package is capable of accommodating up to 4,800 zones on a computer having 512,000 bytes of core storage. By making one minor program modification, the capacity can be varied to conform to the amount of core storage available. The minimum amount of core storage required by the package is about 120,000 bytes.

All data sets either created or used by the package are sequential and may, therefore, be placed on sequential devices such as tape drives or on direct-access devices such as disk drives or data cell drives. There is a total of 22 data sets associated with the package; however, it is doubtful that all of these data sets would ever be used in any one application of the package.

The package is designed to interface with the Texas Large and Small Network Traffic Assignment Packages. It was prepared for, and has been implemented on, IBM 360/50, IBM 370/155 computer systems. Although it is programmed largely on the FORTRAN IV language for these computers, it does take advantage of many options under these operating systems and may require some modification for use on other individual computer installations.

Manuals

The "Operating Manual for the Texas Trip Distribution Package," Research Report 167-1, provides the user with all the information necessary to execute the several programs contained in the package. The information contained in this manual includes: a description of each of the routines available in the package, the format specifications for both data cards and data sets, the error messages which may be encountered in using the packages, a description of the printed information produced by each of the routines, the data sets used or created by each of the routines, and the necessary operational procedures for using the package. A separate document, Research Report 167-2, entitled, "Program Documentation Manual for the Texas Trip Distribution Package" is designed to provide data processing personnel with detailed information and flow charts for the several programs contained in the package. This detailed information on the integral operations of the computer programs is of primary interest to computer programming personnel charged with the responsibility for modifying and maintaining the package.

Other Study Activities

The preceding summarizes the major study activities. Due to the operational nature of the study, however, there remains numerous other activities accomplished under the continuing support objective (i.e., Objective 4). Such activities generally fall in the following areas of activity:

- Assistance in review and evaluation of trip distribution and traffic assignment results for various Texas cities.
- Assistance with problems encountered in the conduct of various urban transportation studies.
- Computer programming support to provide various special purpose programs and to provide assistance with various problems encountered with Job Control Language (JCL) and the IBM operating system.
- Assistance and guidance in the application of the trip distribution and traffic assignment packages.

While individually these activities do not represent substantial levels of effort, collectively they do represent a significant level of effort under Study 167.

List of Reports

The following is a list of reports published under Study 167:

<u>Research Report Number</u>	<u>Title</u>
167-1	Operating Manual for the Texas Trip Distribution Package
167-2	Program Documentation Manual for the Texas Trip Distribution Package
167-3	Program Documentation Manual for the Texas Small Network Package
167-4	Program Documentation Manual for the Texas Large Network Package
167-5	An Evaluation of Induced Traffic on New Highway Facilities
167-6	A Preliminary Evaluation of the Temporal Stability of Trip Generation Rates
167-7	Accuracy of Trip End Estimates from the Home Interview Survey
167-8	Accuracy of Travel Pattern Estimates from the Home Interview Survey
167-9F	Urban Travel Forecasting