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INSTITUTE**

**STATE DEPARTMENT
OF HIGHWAYS AND
PUBLIC TRANSPORTATION**

**COOPERATIVE
RESEARCH**

**URBAN TRANSPORTATION
STUDY
PROCEDURES**

in cooperation with the
Department of Transportation
Federal Highway Administration

RESEARCH REPORT 17-3F

STUDY 2-10-74-17

URBAN TRANSPORTATION STUDY PROCEDURES

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URBAN TRANSPORTATION STUDY PROCEDURES

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Research Report 17-3F

Urban Transportation Study Procedures
Research Study Number 2-10-74-17

Sponsored by the

Texas State Department of Highways and Public Transportation
in Cooperation with the
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Federal Highway Administration

TEXAS TRANSPORTATION INSTITUTE
Texas A&M University
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ABSTRACT

Study Number 2-10-74-17, "Urban Transportation Study Procedures," was originally a three-year planning study. Condensed to a two-year study effort, the technical support and research effort will continue under an interagency agreement contract. Study 17 was directed toward providing continuing technical support for the Texas State Department of Highways and Public Transportation 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 was performed under this study.

The determination of the feasibility and means of theoretically estimating the trip length frequency distribution for "synthetic" urban transportation studies was investigated. The development of a procedure by which the trip length frequency distribution is theoretically estimated resulted. The procedure was tested and compared with the observed trip length frequency distributions from 18 transportation studies conducted in Texas for home-based and nonwork trip purposes, nonhome based, and truck and taxi trip purposes; this procedure was found to yield acceptable results.

The sensitivity of traffic assignment to input from the preceding modeling phases was evaluated. Different random trip matrices were assigned to a network and the resulting assignments were compared to the fully modeled assignment and ground counts. Based on the results of these analyses, a sketch planning approach is proposed which would be expected to produce assignment results of sufficient accuracy for preliminary system evaluation and comparison with other alternatives similarly modeled.

Key Words: "synthetic" transportation study; theoretical trip length frequency distribution; sketch planning; subarea assignment.

Summary

Study 2-10-74-17, "Urban Travel Forecasting," was a two-year research effort directed toward providing technical support to the State Department of Highways and Public Transportation in the conduct of urban transportation studies throughout the State. The third year of this project is to continue under an interagency agreement contract. The activities under this study may be categorized into analytical and operational activities.

The following summarizes some of the more significant analytical activities and their findings:

- The study of observed TLF's from 20 transportation studies led to the development of a procedure for the theoretical estimation of the trip length frequency distribution for urban areas.
- The sensitivity evaluation of traffic assignment demonstrated that, due to the aggregative nature of the assignment procedure, much of the "precision" in the preceding modeling phases can be sacrificed and still produce reasonably accurate assignment results. Subsequent to the results of the sensitivity evaluation of traffic assignment, an abbreviated planning technique is proposed. This sketch planning tool is expected to produce assignment results of sufficient accuracy for valid evaluation and comparison of system alternatives.
- Based on the sensitivity evaluation of traffic assignment, a preliminary development in testing the proposed abbreviated procedure was initiated. Thus far, activities have centered on three facets: trip generation rates, redelineation of zonal structure, and re-coding of the network to a lower level of detail.
- A preliminary test of the proposed subarea assignment procedure was performed to determine if the technique could reasonably replicate the assignment results within a subarea that would be produced by the fully modelled approach. The conclusion reached was that the proposed subarea assignment procedure appeared feasible and practical for implementation.

The operational or computer oriented activities under Study 17 consisted of the following:

- In conjunction with the evaluation of the subarea assignment, a technique is in progress to simplify the delineation of the sector structure and transition ring area. A mechanism is being considered to allow the output of assignment results and statistics relating only to the subarea being studied.

- A detailed review of the Special Area Analyses (SAA) computer programs for air quality analysis and user manual was performed. A computer program was developed and tested to reformat the assignment data sets prepared by the Texas assignment packages for input into the air quality analysis program of the SAA program. Assistance was provided in preparing and collapsing the various tables used as input to the quality analysis program.
- Program modifications were incorporated into the Assign-Self-Balancing routines in both Large and Small Network Packages to modify the impedance adjustment algorithm for capacity-restraint assignments.
- Program modifications were made in both the Large and Small Network Packages, to provide the option to produce separation matrices in miles and thereby provide trip length frequency information in miles. The ASSIGN SELECTED LINKS routines in the Texas Large and Small Network Packages were modified to summarize the selected link information in terms of sectors.

Implementation Statement

The principal research activities produced two significant methodologies. The procedure developed for the theoretical estimation of the trip length frequency distribution can be utilized in both "synthetic" urban transportation studies and future forecasts. The use of this procedure can provide a significant savings in both the man-hours and data requirements presently needed in the estimation of trip length frequency distributions.

The results of the study of the sensitivity of traffic assignment are useful to the transportation analyst in evaluating traffic assignment results. Based on these findings, a "short-cut" (sketch planning) procedure is proposed which is expected to produce assignment results of sufficient accuracy for preliminary system evaluation and comparison with other alternatives similarly modeled.

Program modifications were implemented in the Assign Self-Balancing routines and in the ASSIGN SELECTED LINKS routines to meet the need for options by the State Department of Highways and Public Transportation in the calibration and evaluation of traffic assignment for various urban transportation studies.

Assistance was provided the Department in the implementation of the Special Area Analyses (SAA) Package. This package of programs was used by the Department in the air quality analyses performed for a number of urban studies in Texas.

INTRODUCTION

Study Number 2-10-74-17, "Urban Transportation Study Procedures," is a continuing cooperative research effort between the Texas Transportation Institute (TTI) and the Texas State Department of Highways and Public Transportation. Though initially conceived as a three year study, Study 17 was terminated at the end of two years. This cooperative research effort between the Department and TTI in the area of urban transportation studies will continue under an interagency agreement.

A highly successful cooperative research effort between the Department and TTI in the area of urban transportation studies was developed under Research Studies 2-9-63-60 (terminated on 31 August 1967), 2-10-68-119 (terminated on 31 August 1970), and 2-10-71-167 (terminated on 31 August 1973). During these studies, a close working relationship developed between the research effort of the Institute and the application/implementation by the Department. As a result of this joint effort, significant technological advances have been made in the area of urban transportation studies and significant savings in costs have been realized in the conduct of these studies.

Study 17 was directed toward the continuation of this effort and the provision of continuing support to further advances in the conduct of urban transportation studies. More specifically, the study was intended to impact the following needs:

- the investigation of techniques to further increase the cost effectiveness of urban transportation studies while causing less inconvenience to the public;
- the provision of continued support in the use of computerized study procedures;
- the analysis of trends in trip generation and the development of procedures for convenience in estimating existing and forecasting future trip ends within the framework of a synthetic transportation study.

The objectives of this Study were formulated within this same framework.

Objectives

The objectives of Study 2-10-74-17 did not change since the study was initiated. Two items, however, were added under Objective 1 (i.e., items e and f) to further clarify the types of activities that might be expected under this objective. The objectives of Study 2-10-74-17 are:

1. Assistance to the Texas State Department of Highways and Public Transportation 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 Department.
 - b. The preparation of additional computer programs that may be needed or desirable for more efficient use or implementation of programs and analysis techniques previously developed.
 - c. The implementation of research findings through the use and improvement of models, computer programs, and procedures developed or evaluated under previous research (i.e., studies 2-28-63-60, 2-10-68-119, and 2-10-71-167).
 - d. The development of procedures and techniques for the statewide monitoring of significant travel parameters.
 - e. Assistance in the implementation of other procedures and techniques as requested.
 - f. Assistance in the preparation and presentation of technical workshops on urban transportation study procedures and techniques.
2. 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.

Due to the assignment of higher priorities to work under Objective 1 by the Department and the early termination of the study, no work was initiated under Objective 2.

In addition to these objectives, there were substantial carry-over activities from Study 167 to be completed under Study 17. These activities included:

1. Research Report 167-2, "Program Documentation Manual for the Texas Distribution Package," and Research Report 167-6, "A Preliminary Evaluation of the Temporal Stability of Trip Generation Rates" were revised and published.
2. Research Report 167-7, "Accuracy of Trip End Estimates From the Home Interview Survey," and Research Report 167-8, "Accuracy of Travel Pattern Estimates From the Home Interview Survey," and Research Report 167-9, "Urban Travel Forecasting" were to be completed and published.

While these were carry-over activities from Study 167, they represent significant levels of effort under Study 17.

Significant Accomplishments

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

1. The Department was provided with support such that normal operational activities relative to the processing of urban transportation data were maintained.
2. A number of activities were carried over from Study 2-10-71-167 and completed under this study. Research Report 167-2, "Program Documentation Manual for the Texas Trip Distribution Package," Research Report 167-6, "A Preliminary Evaluation of the Temporal Stability of Trip Generation Rates" were revised and published. Research Report 167-7, "Accuracy of Trip End Estimates from the Home Interview Survey," Research Report 167-8, "Accuracy of Travel Pattern Estimates from the Home Interview Survey," and Research Report 167-9F, "Urban Travel Forecasting" were completed and published.
3. A package of computer programs to assist in trip generation analyses were developed jointly with the Department. The package consists of four integrated computer programs: two of which were developed by the Department and the remaining two were developed by TTI under this study. Subsequent to the original transmittal of the two programs in November 1973, various modifications were made in these programs at the request of the Department.
4. Continued assistance has been provided to the Department in the calibration and evaluation of the trip distributions and traffic assignments for various urban transportation studies (Dallas-Fort Worth, Lubbock, San Antonio-Bexar County studies and, especially, Houston-Galveston).
5. An analysis of trip length frequency distributions for urban areas in Texas was performed. The result of this study was the development of a procedure by which the trip length frequency distribution may be theoretically estimated.

6. Two technical briefings were proposed and presented for personnel of the Department. The first dealt with the assignment algorithm used in the Texas Large and Small Network Package and was presented for personnel of the Planning and Research Division of the Department. The second dealt with the Texas Trip Distribution Model and was presented in Arlington, Texas for Department personnel in the Dallas-Fort Worth Urban Study Office.
7. Program modifications were incorporated in Assign Self-Balancing routines in both the Large and Small Network Packages to modify the impedance adjustment algorithm for capacity-restraint assignments. In addition, the Assign Self-Balancing routine in the Small Network Package was modified to allow the user the option of specifying iteration weights and to provide a restart capability.

Further, program modifications were made in both the Large and Small Network Packages to provide the option to produce separation matrices (i.e., skim tree matrices) in miles and thereby provide trip length frequency information in miles. The ASSIGN SELECTED LINKS routines in the Texas Large and Small Network Packages were modified to provide sector summaries.
8. Assistance was provided the Department in the implementation of the Special Area Analyses (SAA) Package provided by the FHWA. This package was used by the Department in their air quality analyses performed for various urban areas in Texas.
9. A review of the available information of the Community Aggregate Planning Model relative to the potential interface with programs currently being used by the Department for urban transportation studies was performed.
10. Assistance was provided in implementing one of the programs from the UMTA battery for use by the Department in the Dallas-Fort Worth Study.
11. Preparation for the workshops to be jointly developed with the Department was initiated. These preparations were focused in the areas of trip distribution models, modal split models sketch planning techniques, and forecasting of labor force and employment. As of May 1975, the Department decided to indefinitely postpone the workshops and terminate preparations until they can be re-scheduled.
12. The feasibility of implementing a subarea assignment technique was investigated. Based on the findings of this analysis, it was decided to proceed with the preliminary development in testing of the subarea assignment procedure. A preliminary testing of the proposed subarea assignment procedure has been completed under Study 17.

13. A sensitivity evaluation of the traffic assignment procedure was performed. This investigation focused on the sensitivity of traffic assignment results to input from the preceding modelling phases as well as the sensitivity of various commonly used measures of assignment accuracy.
14. Based on the findings of the sensitivity analysis of traffic assignment, an abbreviated procedure was proposed which would be expected to produce assignment results of sufficient accuracy for sketch planning purposes. At the request of the Department, the preliminary development and testing of the proposed abbreviated procedures has been initiated under Study 17.
15. Assistance is being provided the Department in the analysis of special generator count data being collected on a continuing basis throughout the State.
16. At the request of the Department, the ASSIGNED SELECTED LINKS routines in both the Large and Small Packages are being modified to summarize the selected link information in terms of sectors.

SUMMARY OF STUDY ACTIVITIES

Due to the operational nature of the Study 2-10-74-17, the study activities were primarily directed to the provision of continuing support to the State Department of Highways and Public Transportation in the conduct of on-going urban transportation studies. Although the activities generally shared this common goal, the activities themselves were quite varied. The purpose of this section is to provide a summary of the salient findings of the analyses.

A Procedure For The Estimation of the Trip Length Frequency Distributions

Previous research (5) has indicated that interviews of some 400 dwelling units constitutes sufficient data to determine the mean trip length within acceptable limits (e.g., $\pm 10\%$ at the 95% confidence level). Several times as many observations are needed to define the trip length frequency distribution (TLFD). Therefore, availability of a procedure which could be used to estimate the TLFD based on a measure or estimate of the mean trip length could substantially reduce the cost of collecting primary field data. Such a procedure would also be extremely useful to the analyst using the "synthetic" study procedures employed in Texas or in developing future travel forecasts.

The data used in developing and evaluating such a procedure for estimating the TLFD was furnished by the Department and consisted of the observed home-based work and nonwork auto-driver trip length frequency distributions from 20 transportation studies conducted in Texas over the past 11 years.

The statistical measures used in comparing the theoretical and observed distributions were the correlation coefficient (R), the coefficient of determination (R^2), root-mean square (RMS) error, and the Kolmogorov-Smirnov (K-S) goodness of fit test. The value of the R^2 and the K-S test were used as the primary test statistics along with visual comparison of the theoretical and observed distributions plotted together.

Preliminary Analysis

In developing a procedure for estimating the trip length frequency distribution for an urban area, the following characteristics were defined as being desirable:

- The procedure should require as few inputs as possible.
- The procedure should be applicable to all urban areas.
- The procedure should provide an acceptable trip length frequency distribution while maintaining the same mean trip length as observed from sample data or estimated.
- The procedure should be capable of predicting a trip length frequency distribution for a synthetic transportation study and for future forecasts.

Since a trip length frequency distribution is generally presented as the percentage of trips occurring at each separation, the distribution may be thought of as a probability distribution. Other probability distributions might offer an approach to the development of a procedure for predicting trip length frequency distributions. Analysis of previous research lead to a detailed analysis of the Wiebull and Gamma distribution.

Consideration of the Gamma distribution for analysis was on the basis of NCHRP Report 48; this research included the use of the Gamma distribution in fitting observed trip length frequency distributions through the use of the method of Maximum Likelihood. Selection of the Wiebull distribution for analysis was based on previous TTI research which used the Wiebull distribution to fit county income distributions which bear many of the same characteristics as trip length frequency distributions.

Two methods were used to fit observed trip length frequency distributions to each of these probability distributions. The nonlinear least-squares curve fit using the Gamma distribution was ultimately selected as the best approach for detailed evaluation as a procedure for potential application.

Development and Evaluation

Ten urban areas were selected and used to calibrate the parameter values for the Gamma distribution; the calibrated Gamma distribution was then tested using the other 10 observed distributions which were not used in the calibration process. The initial calibration produced good results for all the studies except two; the JORTS* and Sherman-Denison studies. The calibration was then repeated using nine study areas. The two studies which were dropped from the calibration analysis were subsequently considered as special cases.

The best results were always obtained when both the shape parameter and scale parameter were approximately equal. Subsequent analysis revealed that this was due to the nondimensionalization of the distributions before application of the nonlinear least squares curve fit. This nondimensionalized approach reduced each distribution to a common scale, thereby eliminating the relative effect of the scale parameter. Consequently, the scale parameter was set equal to the shape parameter and the Gamma distribution in effect became a one-parameter distribution.

The inputs to the procedure consist of the mean trip length and the maximum trip length which was found to be linearly related to the maximum separation possible.

Theoretical distributions were computed for each of the 18 transportation studies (none of which were used in the calibration and nine of which were used in the evaluation) and compared with the observed distributions. As indicated by the test statistics presented in Table 1 for home based work trips, the procedure yields theoretical trip length frequency distributions that compare favorably with those estimated from the O-D survey. Sets of curves which the analyst can use to select the necessary parameter values were developed.

Figures 1 and 2 show representative plots of the theoretical and observed distributions for several studies. Visual comparisons were made of the other studies as well and those results agreed with the results of the statistical comparisons. In general, all of the results were good.

* JORTS - the abbreviation for the Jefferson-Orange County Regional Transportation Study.

TABLE 1: COMPARISON OF THEORETICAL AND OBSERVED TRIP LENGTH FREQUENCIES
HOME BASED WORK TRIPS

Study	Max Sep		Obs MTL	MTL Dif	R	R ²	RMS Error
	Obs	Est					
Abilene	25	27	6.213	0.0025	0.9929	0.9858	0.5286%
Amarillo	44	42	10.080	0.0041	0.9768	0.9541	0.5906%
Austin*	33	33	9.457	0.0209	0.9908	0.9817	0.4170%
Brownsville*	24	26	6.530	0.0048	0.9635	0.9283	1.1798%
Bryan-College Station*	32	38	7.104	0.0011	0.9727	0.9461	0.8438%
Dallas-Ft. Worth *	95	98	14.142	0.0002	0.9618	0.9250	0.4616%
El Paso	73	68	12.937	0.0005	0.9609	0.9233	0.5722%
Harlingen-San Benito	26	24	5.723	0.0032	0.9555	0.9129	1.4257%
Laredo*	17	15	4.849	0.0266	0.9763	0.9531	1.3571%
Lubbock*	25	25	8.707	0.0859	0.9596	0.9209	0.9711%
McAllen-Pharr*	19	20	5.144	0.0052	0.9823	0.9649	1.0573%
San Angelo*	18	17	6.051	0.0657	0.9855	0.9713	0.8435%
San Antonio	51	60	13.518	0.0026	0.9643	0.9299	0.5470%
Texarkana	22	21	6.025	0.0134	0.9784	0.9573	1.0061%
Tyler	20	18	6.536	0.0816	0.9903	0.9807	0.6536%
Victoria	27	28	5.751	0.0017	0.9749	0.9505	1.0274%
Waco	46	41	9.705	0.0035	0.9689	0.9387	0.7161%
Wichita Falls*	29	27	9.140	0.0746	0.9852	0.9706	0.5785%

TLFD - Trip Length Frequency Distribution

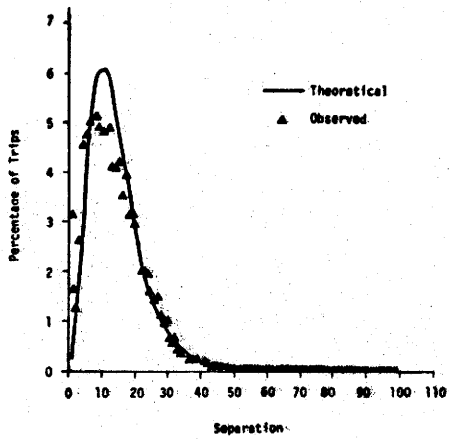
HBW - Home-Based Work

MTL - Mean Trip Length

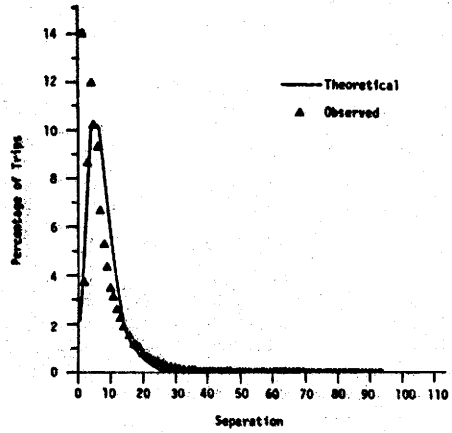
Max Sep - Maximum Trip Length

MTL Dif - Absolute difference between observed and estimated mean trip lengths.

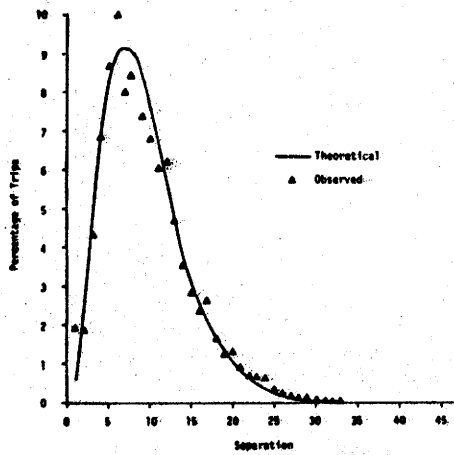
* - Identifies studies used in calibration



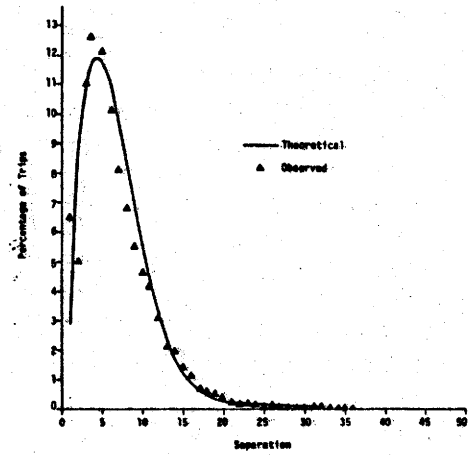
DALLAS - FT. WORTH TRANSPORTATION STUDY (HBNW)



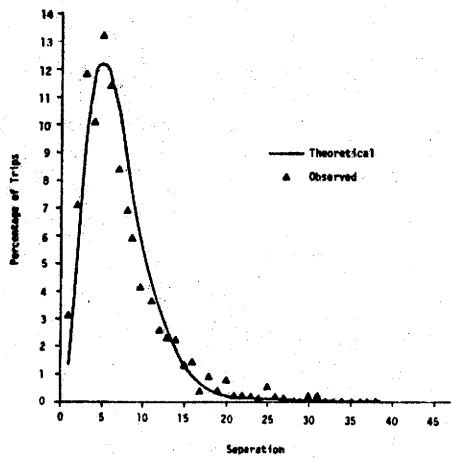
DALLAS - FT. WORTH TRANSPORTATION STUDY (HBNW)



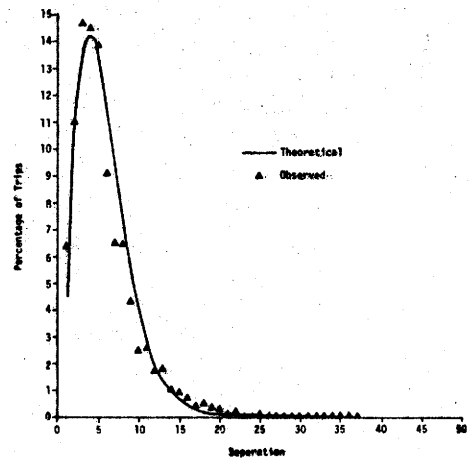
AUSTIN TRANSPORTATION STUDY (HBNW)



AUSTIN TRANSPORTATION STUDY (HBNW)

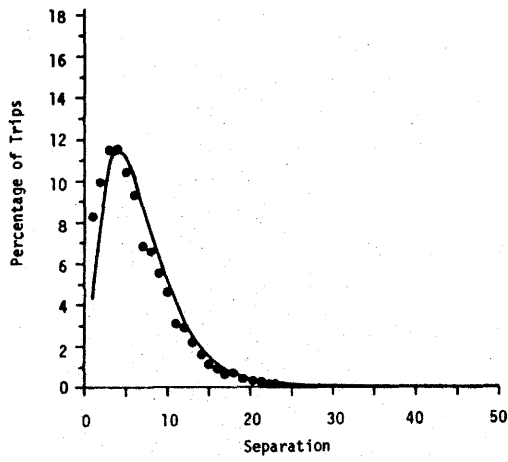


BRYAN - COLLEGE STATION TRANSPORTATION STUDY (HBNW)

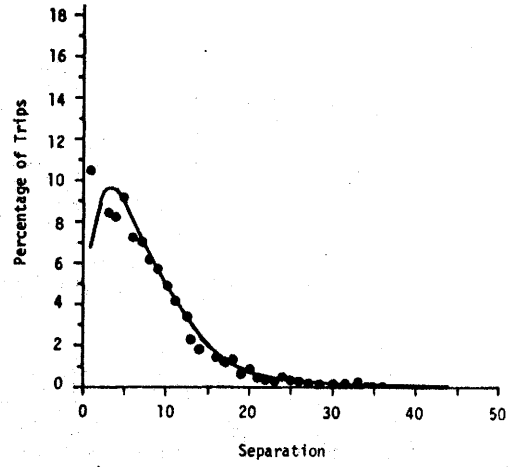


BRYAN - COLLEGE STATION TRANSPORTATION STUDY (HBNW)

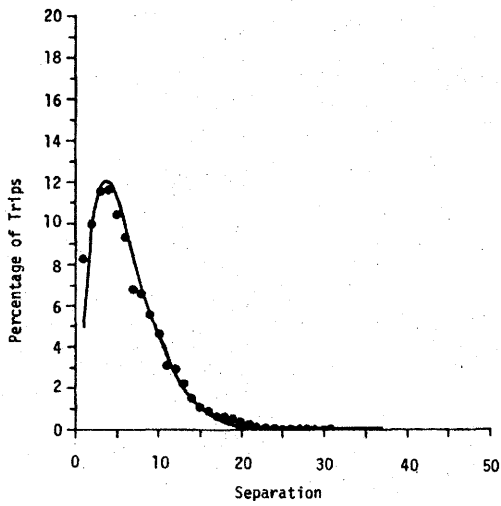
Figure 1. Theoretical and Observed Distribution for HBW and HBNW. Note: Scales differ between graphs.



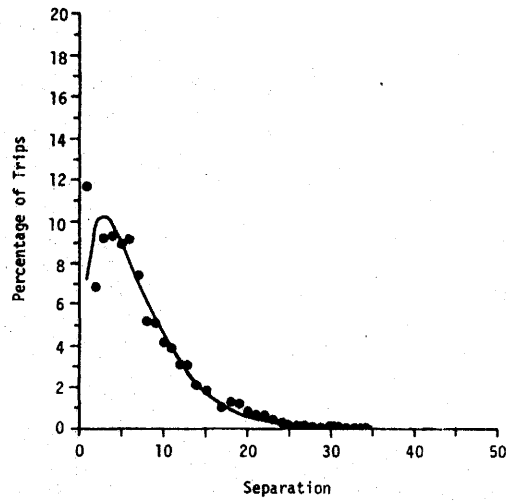
AMARILLO TRANSPORTATION STUDY (NHB)



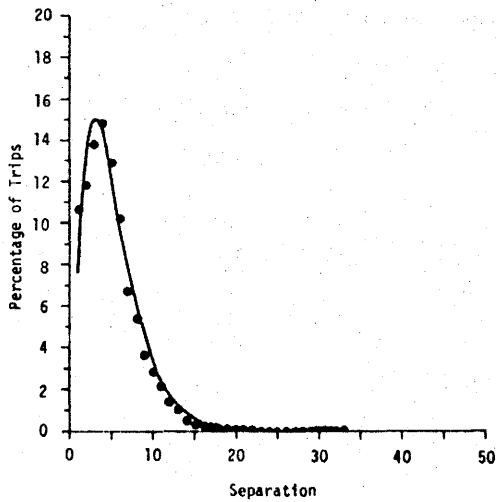
AMARILLO TRANSPORTATION STUDY (TRTX)



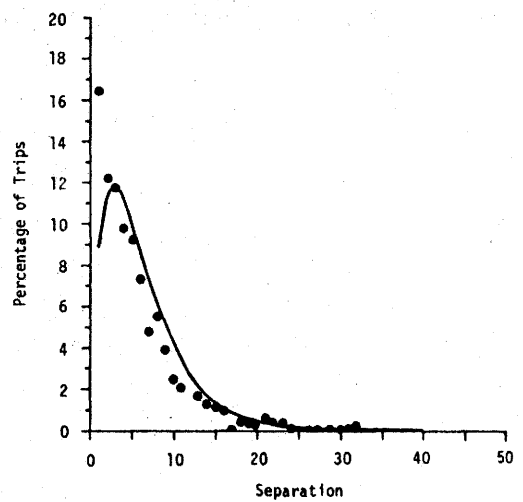
AUSTIN TRANSPORTATION STUDY (NHB)



AUSTIN TRANSPORTATION STUDY (TRTX)



BRYAN-COLLEGE STATION TRANSPORTATION STUDY (NHB)



BRYAN-COLLEGE STATION TRANSPORTATION STUDY (TRTX)

Figure 2. Theoretical and Observed Distribution for NHB and TRTX.

Special Considerations

Two studies, JORTS and Sherman-Denison, were designated as special considerations; an examination of the study areas indicates more than one concentrated urban development with considerable amount of undeveloped land separating the developed area. Consequently, it was hypothesized that the trip length frequency distribution for those areas consisted of several distributions combined. For example, the trip length frequency distribution for the Sherman-Denison area has three TLF's; one for Sherman, one for Denison, and one for trips between Sherman and Denison.

To test this hypothesis, the calibrated procedure was used to produce three theoretical distributions which were combined for comparison with that observed for Sherman-Denison. This resulted in an R^2 of 0.95 and a mean trip length that differs from the observed by only 0.029 "minutes". Therefore, it is concluded that the procedure can be used to produce a reliable estimate of the trip length frequency distribution for special cases such as JORTS and Sherman-Denison.

The influence of intrazonal trips was also considered since their inclusion was believed to be a major reason for the poor results obtained for HBNW trips in larger study areas such as Dallas-Fort Worth. The tests suggested that better results might be obtained if intrazonal trips are excluded when estimating the trip length frequency.

Conclusions

The results of the research indicate that the trip length frequency distribution may be theoretically estimated using only the mean trip length and the maximum separation possible. The procedure as developed can provide a substantial savings in time as well as further reduce the need for expensive origin-destination surveys.

A more detailed account of these analyses and findings are provided in Research Report 17-1, "A Procedure for Estimation of Trip Length Frequency Distributions."

A Sensitivity Evaluation of Traffic Assignment

Of the five basic phases of the modeling process used in urban transportation planning, traffic assignment is the most visible and most widely used (and misused) portion of the total process. Designers use the assignment results for design capacity for an interchange or route; the planner uses the same results to evaluate transportation systems using something more than just intuition.

The nature of the input and the nature of the output (computer print-out that gives an impression of very precise and accurate traffic volumes for each link) lend a very deterministic appearance to the traffic assignment process. This leads many individuals into a feeling of having arrived at *the solution* upon completion of the assignment phase (rather than having arrived at a point where additional information is available for use in evaluation of the alternatives).

Problem Statement

The accuracy of a traffic assignment is dependent upon the reliability of the trip matrix employed. How valid is this statement? The objective of this analysis was to investigate the effects of trip matrices reflecting different degrees of accuracy on various measures of assignment accuracy that are used to evaluate assignment results. Such comparisons provide an evaluation of the power of the assignment process to mask differences in input data. Additionally, analyses of the assignment results produced by different trip matrices provide a means of evaluating the sensitivity of various commonly used measures of assignment accuracy.

Method of Study

A "better-worse" approach was used in developing data for analyzing sensitivity of the measures of accuracy of traffic assignment results. Four different trip matrices were used to generate four different traffic assignment on one network. The existing network for the Tyler, Texas, Urban Transportation Study was selected for test and evaluation; this network offered the following advantages for the purpose of this research:

- Assignment 1 Matrix - a stochastic trip matrix constrained only to the total trips for the urban area.
- Assignment 2 Matrix - a stochastic trip matrix constrained to the total trips as well as the desired trip length frequency for the urban area.
- Assignment 3 Matrix - a stochastic trip matrix constrained to the total trips, the desired trip length frequency, and the desired trip ends at each external station for the urban area.
- Existing Trip Matrix - the fully modeled trip matrix as developed and used in the urban transportation study.

Figure 3 indicates the differences in the distribution of trip ends resulting with the 4 trip matrices. Whereas Figure 1A shows most of the zones in the range of 2,000-2,500 trip ends, Figure 1B shows that constraining to the trip length-frequency results in a considerable increase in the distribution of zonal trip ends. Assignment 3 (Figure 1C) shows the effect of the additional constraint of external station productions in the form of a small "tail" to the right which more closely resembles the fully modeled trip matrix.

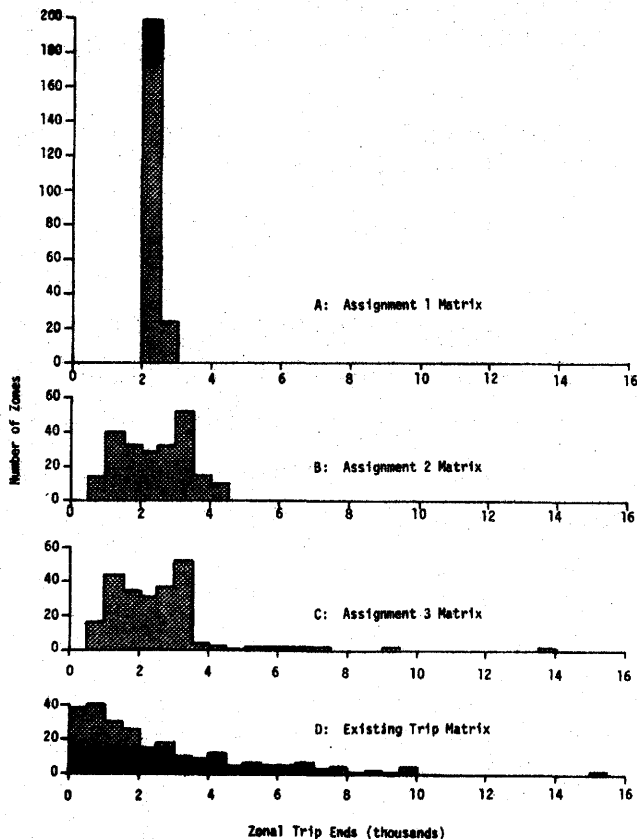


FIGURE 3: DISTRIBUTION OF ZONAL TRIP ENDS

The distribution of zonal interchanges shown in Figure 4 indicates that the Assignment 1 Matrix is essentially uniform and different from the other 3 matrices. The Assignment 2 and 3 Matrices are similar to the Existing Trip Matrix, except for the significantly smaller number of interchanges with zero volume.

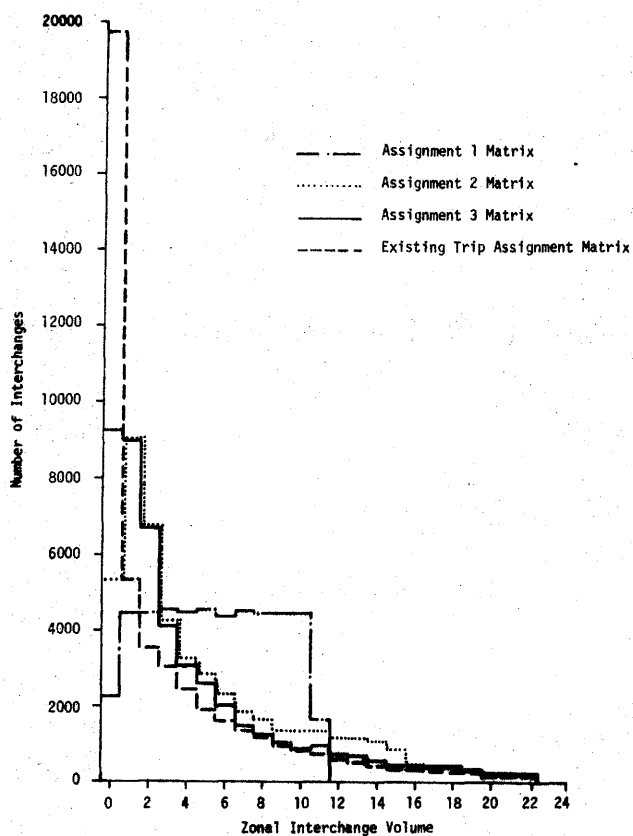


FIGURE 4: DISTRIBUTION OF ZONAL INTERCHANGES

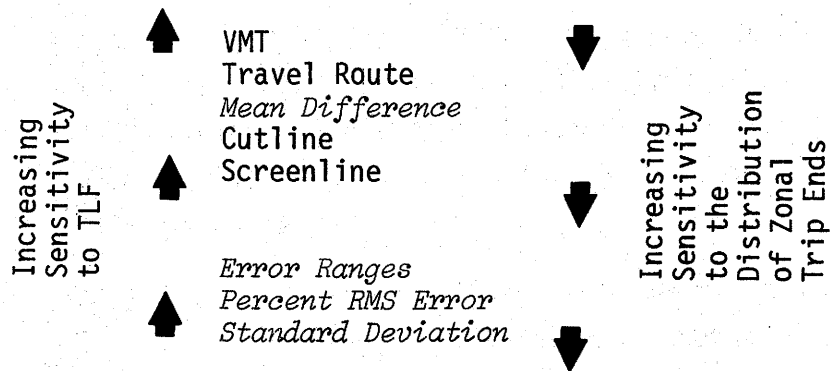
Assignment accuracy was evaluated using a variety of statistical measures, including:

- Vehicle miles of travel (VMT)
- Screenlines
- Cutlines
- Travel routes
- Distribution of link differences by error ranges
- Statistical measures of link differences:
 - mean difference
 - standard deviation of the differences
 - RMS error
 - percent RMS error

Findings

Analysis of VMT results for the all-or-nothing assignments indicates that, as long as an accurate trip length frequency is used in the trip matrix, assigned VMT will very closely match counted VMT, even with a fairly uniform (and unrealistic) distribution of zonal trip ends. On the other hand, three of the micro-level measures tended to show their greatest improvement between a stochastic matrix and the existing trip matrix; thereby indicating a tendency to be more sensitive to the distribution of trip ends.

Measures of goodness such as percent RMS error, error range, and standard deviation (Type II Measures) result in the greatest improvement between Assignment 3 and the Existing Trip Assignment. VMT, travel routes, cutlines, and screenlines (Type I Measures) all showed the greatest improvement between Assignments 1 and 2. Thus, the Type I measures appear to be relatively more sensitive to the trip length frequency than the Type II measures. However, the Type II measures are more sensitive to the distribution of zonal trip ends. The sensitivity of Type I measures and the Type II measures (shown in italics) to the trip length frequency and the distribution of zonal trip ends would appear to relate in the following manner:



This suggests that, as the measures are listed from top to bottom, there is a decreasing tendency to hide matrix inaccuracies.

As a measure of the accuracy of an assignment, VMT is the least discriminating of the 8 measures analyzed, while percent RMS error would appear to be the "best" measure. Standard deviation probably is most sensitive to the distribution of trips; however, it is difficult to know a reasonable value of standard deviation for any assignment because it is so dependent on network size.

Since percent RMS error is calculated in terms of network size, it is judged to be the preferred measure of assignment accuracy. However, the single most important conclusion from these analyses is that several measures need to be used in combination, with full awareness of the strengths and weaknesses of each.

Conceptual Interpretation

As in all urban transportation studies, the Tyler zonal structure reflects the geographical distribution of activities in the urban area. This may be illustrated by subdividing the area into 4 concentric rings: Ring 1 consists of the CBD; Rings 2 and 3 comprise the remainder of the developed urban area; and Ring 4 consists of those zones in the fringe area. As indicated by the data in Table 2, the intensity of activities is reflected by the decline in the desired trip ends per square mile. The number of zones per square mile declined in a similar manner.

TABLE 2: GEOGRAPHICAL DISTRIBUTION OF INTERNAL ZONES AND INTERNAL TRIP ENDS

	RINGS			
	1 (CBD)	2 Developed Urban	3 Developed Urban	4 Fringe Area
Number of Zones	34	28	88	51
Approximate Area in Square Miles	0.25	2.5	22.7	32.6
Average Number of Zones per Square Mile	136	11.2	3.9	1.6
Average Number of Trip Ends Per Square Mile				
• Desired*	138,000	29,000	10,000	2,000
• Resulting from Assignment Matrix 1	297,000	24,000	7,000	3,000
• Resulting from Assignment Matrices 2 & 3	392,000	32,000	7,000	2,000

* Desired trip ends were computed from the Existing Trip Matrix

The application of trip length frequency constraint tended to increase the trip ends in Rings 1 and 2 (i.e., the CBD and the inner portion of a developed urban area). This simply reflects the disproportionate opportunities to travel at the shorter separations (i.e., 1 to 5 minutes) within Rings 1 and 2, which results from the smaller zone sizes in these rings. The zonal structure imposed on the urban area was a major determinant of the trip end distribution resulting from the stochastic matrices. For example, if the zonal structure were redefined such that the CBD consisted of only 2 zones, the resulting trip ends would substantially underestimate the desired trip ends within the CBD. In essence, the zonal structure provided a crude tool for a distribution of activities in the urban area.

Implications Relative to O-D Tables

In operational studies, it is common to compute an origin-destination trip table by expanding the data from the origin-destination survey, and to assign this trip table to the existing network. Previous research, based on a 100 percent home interview survey of three selected zones (4), demonstrated that the estimates of zonal trip ends, based on the expansion of home interview data from that zone, are subject to substantial error. For example, the observed expected error ranges at the 95 percent probability level varied from ± 32 percent to ± 66 percent, when using a 5 percent sampling

rate for a zone containing 424 occupied dwelling units. Other research (5), using the same data base demonstrated that estimates of interchange volumes from expanded survey data are subject to an even greater variance of estimate than the zonal trip ends.

While the expanded O-D trip table is subject to substantial error, in terms of the resulting zonal trip ends and interzonal interchange volumes, these trip tables have generally yielded reasonable assignment results. This had led practitioners to feel confident in the accuracy of their survey data. In reality, the power of the assignment process has been observed to mask inaccuracies at the zonal level (i.e., the trip end estimates) and at the zonal interchange level. The assignment results from the stochastic matrices demonstrate the power of the assignment process to overcome and mask most of the data inadequacies which are encountered in an O-D trip table.

In spite of inaccuracies, the expanded O-D trip tables, like the Stochastic Matrix 3, provide good estimates of total trips and trip length frequency for the urban area, and provide at least a crude estimate of the geographical distribution trip ends and travel pattern. From the perspective provided by the stochastic matrices, it is not surprising that the expanded O-D trip tables have generally yielded reasonable assignment results. Recognition of the variance of estimates associated with these expanded O-D trip tables tends to accentuate and further substantiate the findings from the use of stochastic matrices. It is not surprising that the use of trip generation models, combined with the mathematical modeling of urban travel patterns, have yielded even better assignment results.

Abbreviated Study Procedures

While the comparisons of trip ends and travel patterns indicated there were significant differences between the Assignment 3 and Existing Trip Matrices, the differences in the assignment results were not nearly as significant. This gives some indication of the power of the assignment process, due to its aggregative nature, to overcome inadequacies from the preceding modeling phases.

These analyses suggest that the assignment results are not overly sensitive to the results of the preceding modeling phases (i.e., the trip generation and trip distribution phases). It is proposed, therefore, that a simplified or "short-cut" trip generation analysis procedure might be utilized for "first-cut" system evaluations. The following generally describes a proposed simplified trip generation procedure for such analysis.

To implement such a procedure, the land use patterns might be described via a map reflecting the desired land use categories. The desired zonal structure may then be superimposed upon the map. The land use categories should be kept reasonably simple but of sufficient detail to reasonably describe the urban area being studied. Small urban areas would generally require fewer categories than large urban areas. Table 3 summarizes typical land use categories which might be utilized in large and small urban areas. In addition, the analyst may wish to utilize a number of special land use categories to handle unusual situations.

With a description of the land use categories in each zone (i.e., the number of acres or number of units of each land use category within a zone), a set of vehicle trip generation rates consistent with the land use categories may be applied to determine the zonal productions and attractions. It is proposed that only 4 trip purposes need be used: Home-based trips, Nonhome-based trips (including truck and taxi), External-local trips, and External-through trips.

In short, given a land use map, an experienced transportation analyst can utilize a simplified trip generation procedure to estimate zonal productions and attractions. Such an approach would provide a significantly better geographical distribution of trip ends than observed with the stochastic matrices; therefore, assignment results should be significantly closer to those of the Existing Trip Matrix.

TABLE 3: TYPICAL LAND USE CATEGORIES FOR SIMPLIFIED TRIP GENERATION ANALYSIS

LARGE URBAN AREAS	SMALL URBAN AREAS
<p>Residential (in acres):</p> <ul style="list-style-type: none"> ● Low Density (i.e. single family dwelling units) ● Medium Density (e.g. garden apartments etc.) ● High Density (e.g. High rise apartments) ● Other (e.g. mobile home parks etc.) 	<p>Residential (in acres):</p> <ul style="list-style-type: none"> ● Low Density (i.e. single family dwelling units) ● Medium Density (e.g. garden apartments etc.) ● Other (e.g. mobile home parks etc.)
<p>Commercial (in acres):</p> <ul style="list-style-type: none"> ● Organized shopping (such as regional shopping centers) ● Unorganized shopping (such as strip development) ● Major Office Complexes ● Other 	<p>Commercial (in acres):</p> <ul style="list-style-type: none"> ● Organized Shopping (such as regional shopping centers) ● Unorganized shopping and office development (strip development)
<p>Industrial (in acres):</p> <ul style="list-style-type: none"> ● Heavy Industry (such as automobile assembly plants, etc.) ● Light Industry (such as electronic components) 	<p>Industrial (in acres):</p> <ul style="list-style-type: none"> ● Heavy Industry ● Light Industry
<p>Other (as appropriate)</p>	<p>Other (as appropriate)</p>

Using the results from such a trip generation analysis and an estimate of the trip length frequency, it would seem reasonable to expect that the analyst could use a traditional trip distribution model to estimate the urban travel pattern.

Due to the aggregative nature of the assignment procedure, many differences that may be observed at the zonal level and zonal interchange level tend to disappear in the assignment results. This implies that much of the "precision" in the preceding modeling phases (i.e., trip generation and trip distribution phases) can be sacrificed and still produce reasonably accurate assignment results. Therefore, abbreviated or sketch planning techniques should produce assignment results of sufficient accuracy for valid evaluation and comparison of system alternatives.

A detailed account of these analyses and findings is reported in Research Report 17-2, "A Sensitivity Evaluation of Traffic Assignment."

Implementation of SAA Package

Assistance was provided the Department in the implementation of the Special Area Analyses (SAA) Package provided by the FHWA. This package of programs was used by the Department in the air quality analysis performed for a number of urban studies in Texas. The following briefly summarizes the assistance provided under Study 17.

Initially, a detailed review of the SAA computer programs for air quality analysis and user manual was performed to identify the data required by these programs, identify the data incompatibility, identify the various options available to the user of the package, and formulate an approach to providing an interface between the Texas Large and Small Network packages and the SAA package. A similiar but less detailed review was also performed for the noise analysis and accessibility analysis programs in the SAA package. A computer program was then developed and tested which reformatted the assignment data sets prepared by the Texas assignment packages for input into the air quality analysis program of the SAA package. TTI staff worked closely with the Department personnel throughout the implementation of the SAA package. Assistance was also provided in preparing and collapsing the various tables used as input to the air quality analysis program.

Following the preliminary runs for Wichita Falls (the test site selected by the Department), an error was detected in the SAA package in the computation of the off-the-networks (or background) pollutants. Careful review of the SAA programs by TTI staff identified the problem as a missing statement in one of the subroutines. The error was corrected by the TTI staff so that the Department might proceed with its analyses.

In comparing the results of the 1990 traffic on the proposed system versus the 1990 traffic on the 1975 system (no-billed), it became obvious that a logic problem existed in the SAA package. Estimates in larger portion (percent) of the vehicle miles were allocated as heavy duty vehicles for the proposed system than for the no-billed option. While it is reasonable to expect that the vehicle miles of travel on the 1990 network would

exceed that of the 1990 traffic on the 1975 network, there seemed little reason to believe that a larger portion of the increased vehicle miles would be attributable to the heavy duty vehicles. To handle this situation, a procedure was developed so that the input tables to the package could be adjusted to hold the vehicle miles attributable to heavy duty vehicles to a constant percent. A computer program was developed to assist the analyst in adjusting these tables.

Preliminary Development and Testing of Subarea Assignment Technique

In urban transportation studies dealing with large urban areas, it is often desirable to consider alternatives which basically affect only a portion of the urban area. The cost of rerunning the distribution and assignment models for large metropolitan areas become exorbitant. As a result, interest has been focused on techniques whereby only a portion of the area might be studied and the alternatives examined at a reasonable cost. At the request of the Department, the feasibility of implementing a subarea assignment technique has been investigated.

Above all, the subarea assignment is primarily applicable in large urban areas due to the relatively low cost of running the distribution and assignment models in small urban areas. In considering the problems which may be addressed by the subarea assignment technique, it is assumed that distribution and assignment models have been run for the entire urban area and that the analyst is interested in examining some specific alternatives for a few select subareas.

A subarea assignment technique is primarily applicable to problem situations involving either major changes in the transportation system or major land use changes or both. The basic distribution and assignment models are not sufficiently sensitive to minor changes to produce reliable data for evaluating such alternatives.

The initial subarea assignment technique which was to be considered for implementation involved determining a cordon line around the selected subarea so that all traffic entering or leaving the subarea would be

treated as "external" traffic relative to the subarea. Such a technique might involve obtaining selected link assignments for each link crossing the subarea cordon. This information together with the trip matrix for the entire urban area might then be used to determine a trip matrix for the subarea.

This technique is characterized by the following limitations:

1. Since the trip matrix for the subarea is more a condensation of the trip matrix for the entire urban area, the technique essentially ignores the impact of land use changes on travel across the subarea cordon. In other words, the technique is applicable only in situations in which the land use pattern remains relatively constant.
2. By holding the trip matrix essentially constant, the technique largely ignores the impact of the transportation system itself, on the urban travel pattern (i.e., a major system change might change the skim tree matrix sufficiently to impact the travel pattern).
3. The technique basically only allows the rerouting of traffic within the subarea. By holding the trips entering or leaving the subarea at the subarea cordon line constant, the technique essentially assumes that this traffic continues to enter and/or exit at these points regardless of any transportation system changes. Thus, the technique provides little or no opportunity for rerouting traffic either through or around the subarea.
4. The cost associated with obtaining selected link assignments for all links crossing the subarea cordon line is substantial. Since the subarea would likely not be identified before the initial assignment, this approach would probably require rerunning the assignment for the entire urban area to obtain the selected link output. This is not practical unless a number of alternatives were to be studied for the subarea.

Since the initial approach considered did not appear desirable for implementation, an alternate approach was sought which would provide more flexibility and produce more reliable results.

Proposed Alternative Procedure

The distinguishing trait of the proposed technique is that of a holistic approach in contrast to the previous fragmented orientation. A subarea is not adequately analyzed in isolation from the surrounding urban milieu; the dynamic interactions need to be incorporated into the algorithm if the

technique is to be reliable. The proposed algorithm for subarea assignments incorporates both a trip distribution phase and a traffic assignment phase. the latter enables the analyst to look at alternatives involving different land uses. In addition, it furnishes a mechanism to account for the impact of transportation system changes.

The initial step when using the proposed algorithm is to delineate the subarea of interest together with a five- to seven-mile "transition ring" surrounding the subarea. The subarea and transition ring will be indentified by simply enumerating the zones in each. The remainder of the urban area is described via a sector structure in which the sector sizes would increase as the distance increases from the subarea. In describing each sector, the algorithm will require that a zone within the sector be designated as the "sector centroid" which is analogous to the zonal centroid concept.

If the subarea alternative to be studied involves transportation system changes, then the network for the entire urban area (link data cards) needs to be modified to reflect these changes within the subarea. Likewise, if the subarea alternative to be studied involves land use changes, the zonal production and attractions by trip purpose for the zones in the subarea should be modified to reflect the new land uses.

Once the analyst is ready to build trees and skim trees, a modified version of the Build Tree Program for the Large Network Package is employed. Trees are built only for the zones in the subarea, transition ring and for each zone designated as a sector centroid. In this way only a small subset of the trees for the urban area are built, thereby, considerably reducing the computer costs.

Once the trees and skim trees are built for the proposed subarea, new distributions may be run for each trip purpose using a modified version of the Texas Trip Distribution model. It is currently proposed that the modified distribution model might iterate on attractions only using the trip length frequency factors previously determined from the full model runs. In this way, additional cost savings are derived.

At this point, the output from the "build trees" phase of the subarea assignment and the new trip table are ready for input into the Load Network Program. While the assignment results might be output for the entire network, only the portion of the assignment results associated with the portion of the network within the subarea would be valid for study and evaluation.

Based on the findings of the feasibility analysis, it was decided to proceed with the preliminary development and testing of the proposed approach under Study 17.

Preliminary Tests

The preliminary test of the proposed subarea assignment procedure was designed to determine if the subarea assignment technique can reasonably replicate the assignment results within a subarea that would be produced by the full modelling approach. The 1990 Houston-Galveston Regional Assignment was selected as the data base for this test. The subarea to be studied is located along the West Belt of Houston. The subarea comprises 37 zones and the transition ring comprises 157 zones. The remaining 2,869 zones were grouped into 81 sectors. The 1990 Houston-Galveston trip table was then collapsed so that each line in the trip table corresponded to either a zone in the subarea or transition ring or a zone centroid of a sector. By using the "collapsed" version of the fully modelled trip table, it is possible to determine if the subarea assignment procedure itself can reasonably replicate the results from the full assignment model. The next phase of the preliminary tests will then focus on the trip distribution phase to determine if an abbreviated trip distribution model can produce a trip table which reasonably replicates the full modelling results for the subarea.

Using the collapsed trip table, a subarea assignment was produced. While the link loadings in the subarea varied somewhat from the fully modelled results, it was felt that these differences were not of sufficient magnitude to be significant. At the conclusion of this phase of the preliminary tests, it was concluded that the proposed subarea assignment procedure still appeared feasible and practical for implementation. These preliminary results are currently being reviewed by the Department before proceeding with other tests and evaluation.

Refinements Being Considered

In proceeding with the preliminary tests, it was found that the delineation of sectors external to the subarea and transition ring was cumbersome and time consuming as well as being subject to considerable error. It was requested, therefore, that techniques to simplify this phase of data preparation be investigated. The following describes a potential approach which was identified that should considerably simplify the data preparation phase and at the same time reduce the likelihood of error. Under this approach, the analyst would be asked to provide the following information:

1. A list of all zones contained in the subarea to be studied.
2. A list of all zones contained in the transition ring enclosing the subarea.
3. The zone numbers of all zones to be used as sector centroids.

Using this information along with a separation matrix for the urban area, a computer program may be used to equate all remaining zones to their nearest sector centroid. This approach would partially automate the data preparation phase by eliminating the necessity for enumerating the zones within each sector.

A second improvement currently being considered would provide the mechanism for outputting only assignment results and statistics relating to the subarea being studied. Such a procedure will require the analyst to enumerate a set of links which completely enclose the subarea to be studied. Using this information, a computer program can be used which identifies all remaining links within the subarea. Output assignment results and statistics would relate only to the subarea being studied. It is felt that this would be extremely useful for comparing subarea alternatives.

Preliminary Testing of Abbreviated Procedures

The utility of "short-cut" analysis tools or sketch planning tools to evaluate land use/transportation system alternatives has come to the forefront of attention during the past few years. The sensitivity evaluation

of the traffic assignment procedure performed under this study suggests that an abbreviated procedure might be implemented which would provide sufficiently reliable assignment data for first-cut system evaluation. Based on the findings of these analysis, the Department decided to initiate the preliminary development and testing of this proposed abbreviated procedure under Study 17. Although initiated under Study 17, the preliminary development and testing will be carried forward under the Interagency Agreement with the Department during the next fiscal year.

The 1970 Austin Urban Transportation Study data were selected as the data base for use in the preliminary development and testing of the proposed abbreviated procedure. To date, the work activities have focused primarily on: the establishment of trip generation rates useful for application in such a sketch planning environment, the redelineation of the zonal structure, and the recoding of the network for Austin to a lower level of detail for sketch planning purposes.

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. 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 17.

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